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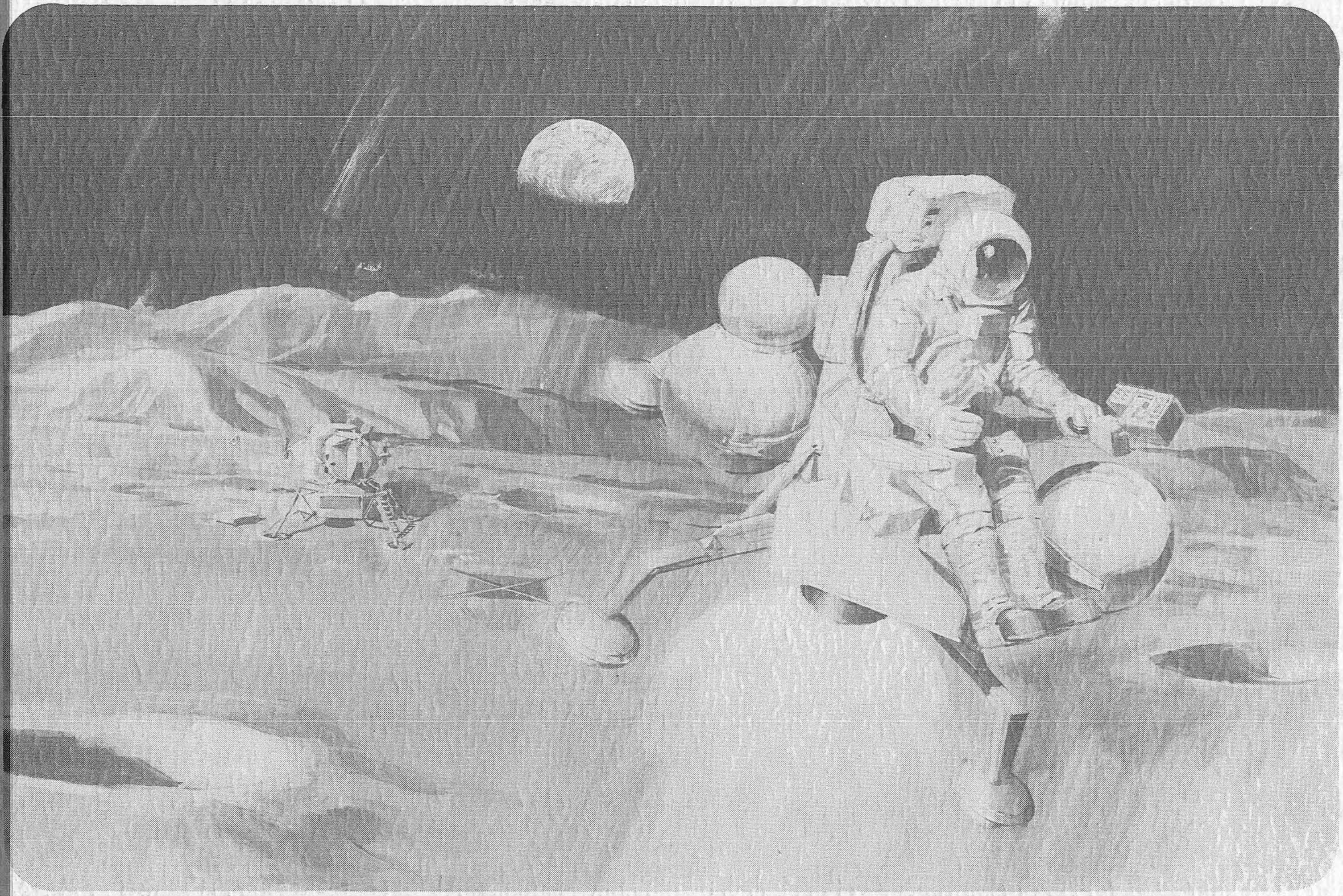

Study of ONE-MAN LUNAR FLYING VECHICLE FINAL REPORT

Volume VI
Training and Resources Plans

Space Division
North American Rockwell

NASA CR 101923

SD 69-419-6

STUDY OF ONE-MAN LUNAR FLYING VEHICLE
FINAL REPORT

VOLUME VI
RESOURCES AND TRAINING PLANS

Contract NAS9-9045

31 August 1969

FOREWORD

This volume contains the training and resources plans for the one-man lunar flying vehicle. This work was accomplished under the One-Man Lunar Flying Vehicle Contract (NAS9-9045), conducted by the North American Rockwell Space Division for the National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas. Other volumes to this report are:

Volume 1. Summary
Volume 2. Mission Analysis
Volume 3. Subsystem Studies
Volume 4. Configuration Design
Volume 5. Preliminary Design and Specifications

TECHNICAL REPORT INDEX/ABSTRACT

ACCESSION NUMBER	DOCUMENT SECURITY CLASSIFICATION
	UNCLASSIFIED

TITLE OF DOCUMENT
STUDY OF ONE-MAN LUNAR FLYING VEHICLE - FINAL REPORT: VOLUME 1 - SUMMARY; VOLUME 2 - MISSION ANALYSIS; VOLUME 3 - SUBSYSTEM STUDIES; VOLUME 4 - CONFIGURATION DESIGN; VOLUME 5 - PRELIMINARY DESIGN AND SPECIFICATIONS; VOLUME 6 - TRAINING AND RESOURCES PLANS

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DESCRIPTIVE TERMS
*ONE-MAN LUNAR FLYING VEHICLE, *CONTROL SYSTEMS, *PROPULSION SYSTEMS, *TRAJECTORIES, *DESIGN, *TRAINING, *RESOURCES, *MISSION ANALYSIS

ABSTRACT

THE PRIMARY OBJECTIVES OF THIS STUDY WERE TO OPTIMIZE THE DESIGN AND TO DEVELOP SYSTEM SPECIFICATIONS OF THE LUNAR FLYING VEHICLE. THE SCOPE ENCOMPASSED PARAMETRIC INVESTIGATIONS, CONCEPT GENERATION, AND EVALUATION EFFORT FOR THE DEFINITION OF A RECOMMENDED CONCEPT; PRODUCTION OF A PRELIMINARY DESIGN AND DEVELOPMENT OF SYSTEMS SPECIFICATIONS OF THE RECOMMENDED CONCEPT; AND DEFINITION OF RESOURCES AND CREW TRAINING PLANS. IN ADDITION TO GENERATION OF THE LFV DESIGN, THE SCOPE OF THE STUDY INCLUDED LUNAR MODULE INTEGRATION, FLIGHT SUIT INTERFACE STUDIES, AND DEFINITION OF GROUND SUPPORT EQUIPMENT FOR EARTH AND LUNAR OPERATIONS.

AS A RESULT OF PARAMETRIC STUDIES CONDUCTED DURING THE FIRST PHASE OF THIS EFFORT, A CONCEPT WAS SELECTED WHICH HAS THE FOLLOWING CHARACTERISTICS: (1) STABILITY-AUGMENTED CONTROL, (2) FOUR GIMBALED ENGINES WHICH ARE CLUSTERED BENEATH THE VEHICLE, (3) A SEATED PILOT POSITION, AND (4) AN INTEGRAL X-FRAME LANDING GEAR WITH 6 HYDRAULIC ATTENUATORS. THIS VEHICLE IS CAPABLE OF CARRYING A 370-LB PAYLOAD IN ADDITION TO THE PILOT. THE DRY WEIGHT OF THE VEHICLE IS 304 LB. WHEN LOADED WITH 300 POUNDS OF LM DESCENT STAGE PROPELLANTS, THE VEHICLE CAN OPERATE WITH A 4.6 NAUTICAL MILE RADIUS WITH NO PAYLOAD.

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INTRODUCTION AND SUMMARY

This volume presents the plans for two prime areas: (1) the plans associated with detailed design, development, and fabrication of the lunar flying vehicle system, and (2) the plans associated with training of the astronauts to utilize the system in lunar operations.

The first part contains the results of an analysis conducted to define the resources required for the Phases C and D one-man lunar flying vehicle activities. The elements of this plan include a description of the approach used to obtain the resources data, a program summary, development plans for certain key functional areas, and a summary of cost data. The Program summary section presents the work breakdown structure, the overall schedule, and a subschedule for the propulsion system. The Program Development Plans section contains a preliminary description of the development plans for engineering, manufacturing, test, material, and facilities. Program costs and manpower are summarized in the final section of Part 1.

The second part presents the astronaut training plan. This plan defines general flight crew behavioral objectives and the training support for the operational aspects of the one-man lunar flying vehicle program. Specifically, it identifies the training phases, training program curriculum, and estimates costs related to the LFV contractor participation in the training program and the primary training hardware. The appendix briefly discusses the requirements for visual and flight simulators.

PART 1

RESOURCES PLAN

1. RESOURCES PLAN

APPROACH

The approach in developing cost and schedule data for the resources plan is illustrated in Figure 1. The recommended system was employed to obtain a work breakdown structure and preliminary systems specification. An overall schedule, based on the work breakdown structure, was developed and a preliminary make and buy list established. These data, along with preliminary subsystem specifications, were used to obtain estimates from appropriate subcontractor sources.

Space Division functional personnel were briefed on the LFV mission and system, and were requested to provide task descriptions, manpower, and other cost estimates based on the schedule and keyed to the work breakdown structure. These estimates, along with subcontractor estimates, were then employed to determine program cost.

Key preliminary development plans were also prepared by certain critical functional areas. These data were then integrated to form the resources plan contained in this volume.

Subcontractor data sources, listed in Table 1, were selected on the basis of their current development of the required hardware (for example, propellant tanks and hand controller) or for their already-displayed competence in development of the required subsystems.

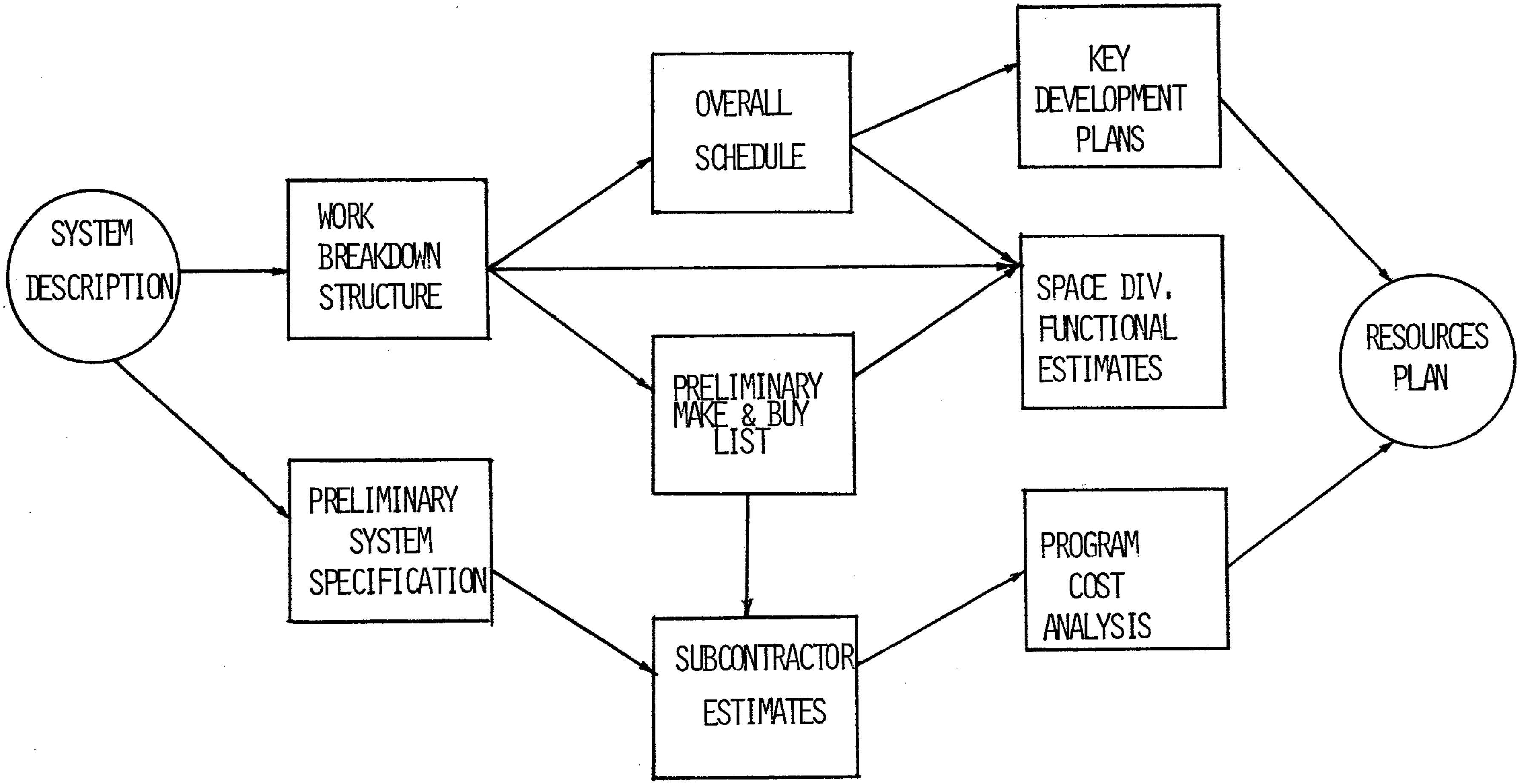


Figure 1. Resources Plan Approach

Table 1. Subcontractor Data Sources

Vehicle Items	Subcontractor Data Source
Propulsion	
Propellant tanks	Fansteel Corp. Airite Division
Engines	Bell
	TRW
	Rocketdyne
	Marquardt
	Aerojet
Controls	
Actuators	Cadillac Controls Autonetics
Gyros	Honeywell
Control unit	Honeywell Autonetics
Hand controller	Honeywell
Servo amplifiers	Honeywell
Attenuators	National Water Lift Co.

PROGRAM SUMMARY

Because of the requirement for rapidly developing the lunar flying vehicle system, Phases C and D were assumed to be combined and overlapping.

WORK BREAKDOWN STRUCTURE

The work breakdown structure (Figure 2) is end-item oriented and includes all elements of Phases C and D. No end items associated with astronaut training are included. These are contained in Part 2 of this volume.

In developing this work breakdown structure (WBS), the elements required for typical manned spacecraft programs were assumed to be required. These elements are shown in Figure 2, which includes as second-level elements program management, program plans, lunar flying vehicle system (operational articles), lunar flying vehicle specification, and development test articles. For costing and developing tasks, the program plans, lunar flying vehicle system, and support equipment were broken down to a level deeper than those shown in Figure 2. Five operational flying vehicles were assumed in the cost estimate. The development test articles include one landing test vehicle, two mockups (one a low-cost mockup of the general arrangement and the other a "house-bird" with engineering test quality subsystems), one thermal test vehicle, one structure test vehicle (for static load testing and dynamic tests), one integrated propulsion/stability and control system test vehicle, and one propulsion breadboard system. These are further described in the preliminary test plan.

PROGRAM SCHEDULES

The schedule for design, development, and delivery of the lunar flying vehicle is shown in Figure 3. The assumed program initiation date is October 1969 and flight-readiness review for the first flight article is scheduled during April 1972. All subcontract designs are frozen and preliminary design review will be completed five months after contract initiation. The long leadtime engine subcontract procurement action will begin one month after contract initiation and delivery of qualified hardware is planned by October 1971. Five operational flight systems are assumed in the delivery schedule.

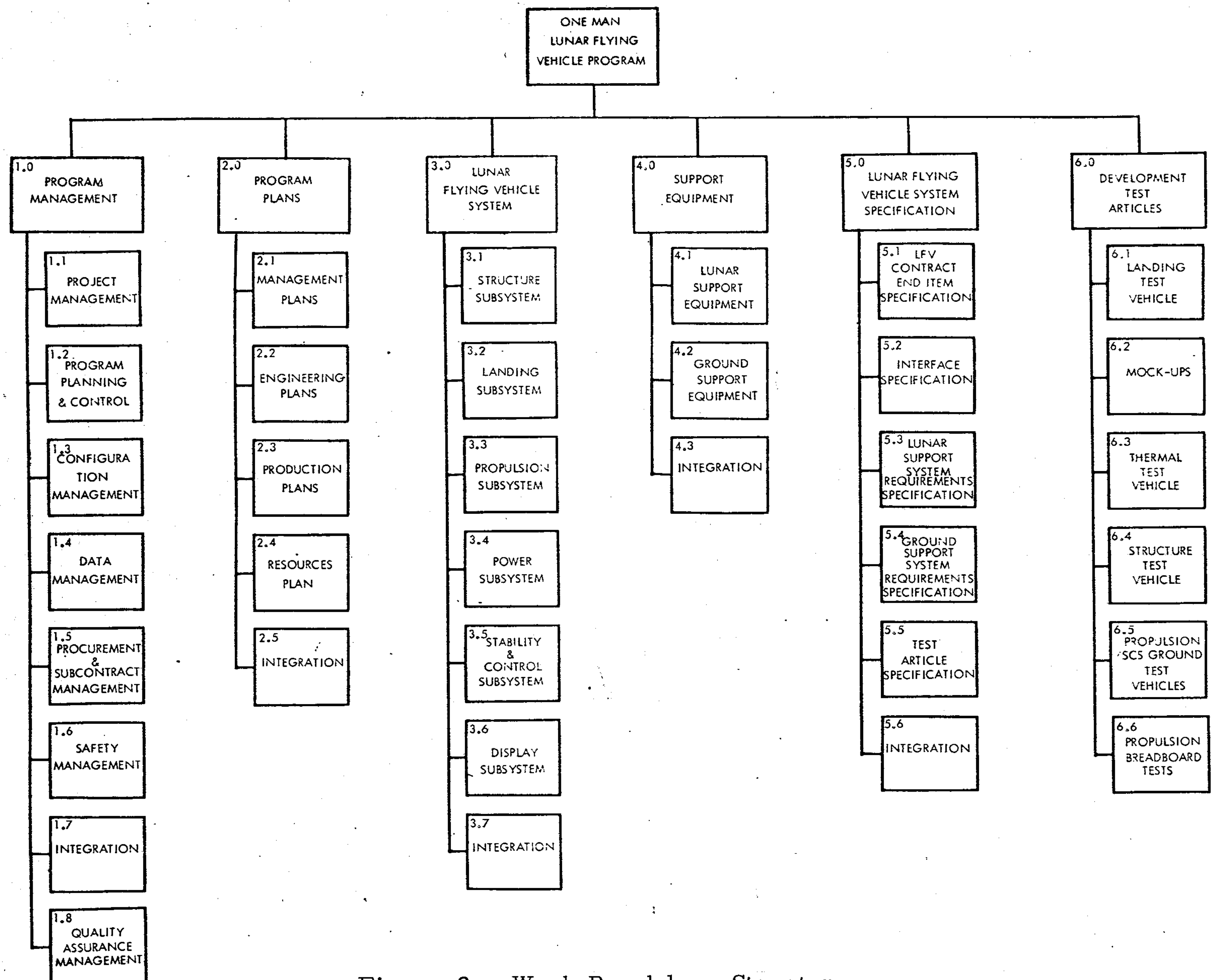


Figure 2. Work Breakdown Structure

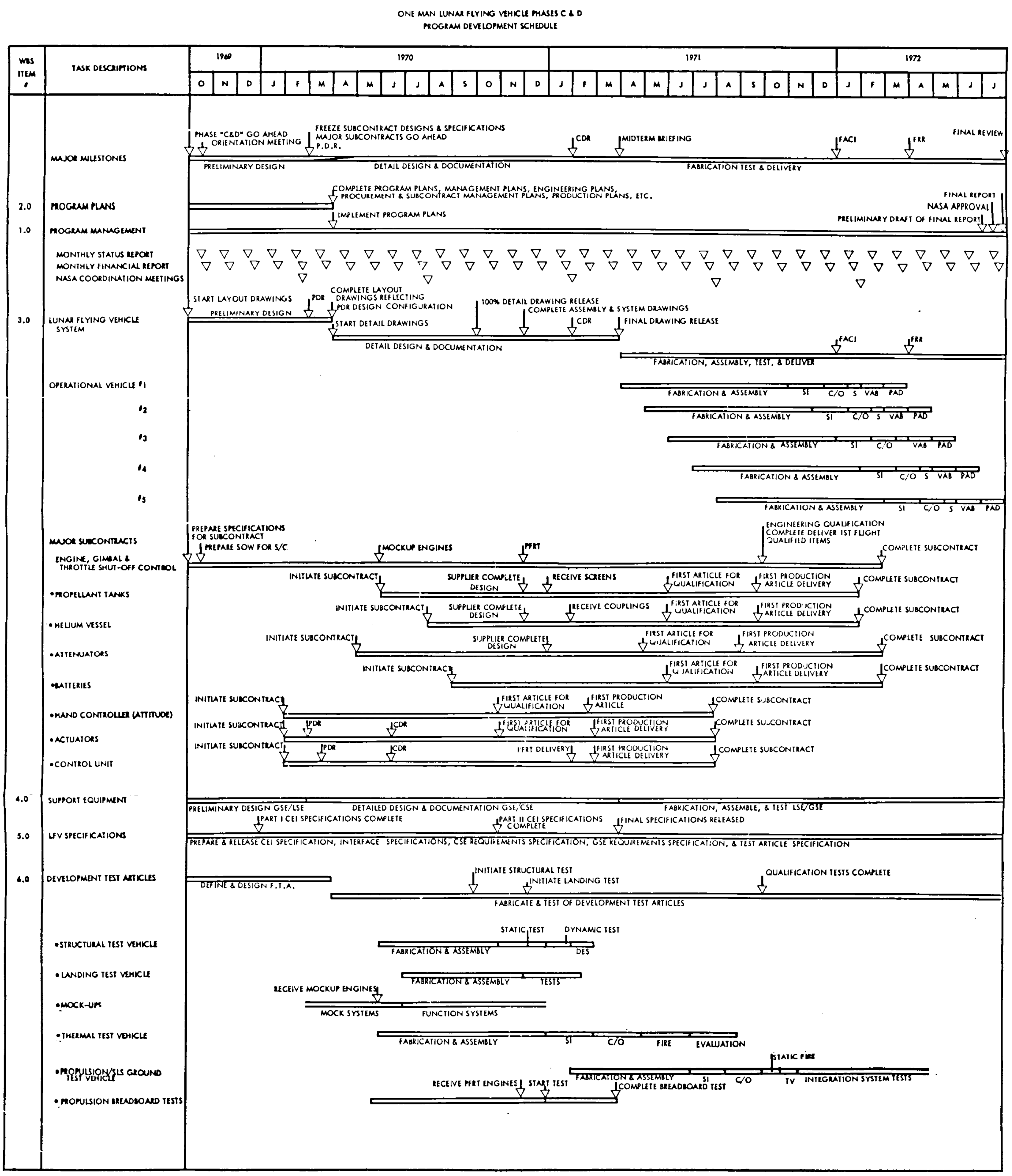


Figure 3. One-Man LFV Phases C and D Program Development Schedule

A more detailed schedule for the propulsion system is presented in Figure 4. This schedule includes the primary milestones associated with all propulsion subsystem hardware, including engines, propellant tanks, helium tanks, valves, and couplings.

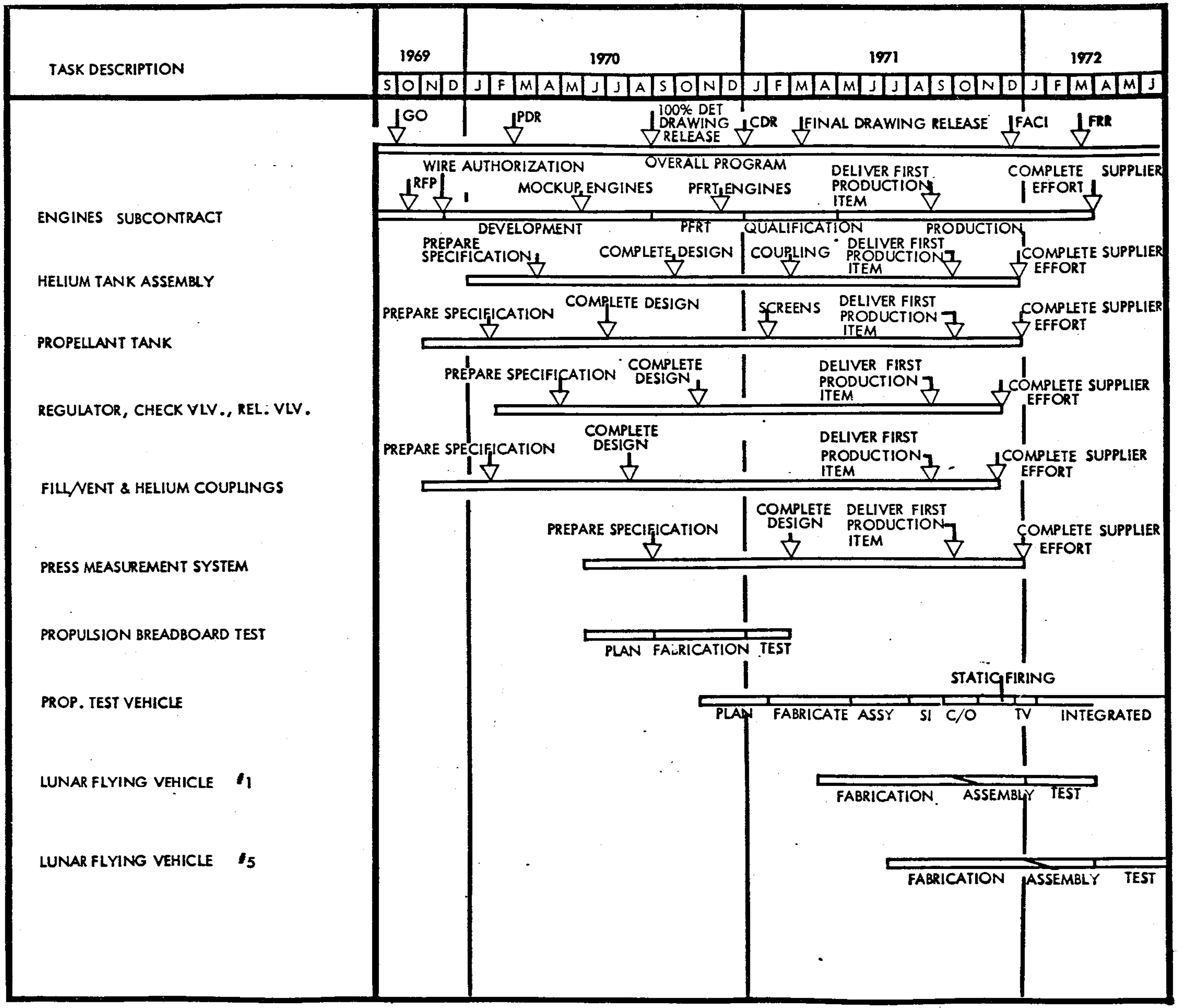


Figure 4. One-Man LFV Propulsion Subsystem Schedule

PROGRAM DEVELOPMENT PLANS

During Phase C (design), program plans will be prepared to ensure timely accomplishment of all Phases C and D tasks. At that time the programmatic and technical requirements of the evolving program will be thoroughly assessed. This assessment will be iterated so that requirements are consistently defined and all interfaces identified. A methodology will be established for implementation of all needed plans. By this approach the plans will be developed as an element of the total management process and will not evolve independently of the main program effort. This will result in a series of cohesive program plans that, when implemented, will provide all of the necessary direction to assure the highest confidence in carrying out each stage of the program to its successful conclusion.

As evidence of the nature of the plans that will be developed later under Phase C, a select group of representative preliminary program plans have been prepared. These plans, presented on the following pages, include engineering, manufacturing, test operations, material, and facilities. In developing these preliminary plans, careful attention was given to providing specific program detail rather than a generalized outline. There is a high correlation between these plans and the master program schedule and work breakdown structure, thus assuring the greatest realism possible.

ENGINEERING PLAN

Purpose

The engineering development plan summarizes the planned orderly progression of engineering activities, i.e., analysis, design, development, and test and evaluation required for conducting Phases C (design) and D (development/operations) of the Lunar Flying Vehicle Program.

Scope

The engineering development plan presents the initial engineering approach. However, it will be expanded to levels of greater detail during the design phase (NASA Phase C). In the past several years, the NR Space Division has developed a unique capability to define and implement effective technical management systems for large programs. This capability, in the form of an integrated program management process, consists of functional models of generic program operations and major integrating processes.

Used as a baseline, this process has been carefully analyzed and tailored to meet the specific requirements of the Lunar Flying Vehicle Program. The NR approach has been designated the LFV program engineering process (PEP). The intent of this approach is to establish a flexible integrated engineering process for defining system performance requirements, providing traceability of technical decisions, design verification, technical planning and control, evaluation of technical interfaces, design and performance integration, and analysis of development tests.

Summary of Tasks

The PEP is shown in Figure 5. This flow chart presents all the technical functions required to fulfill the engineering commitments in the development of the LFV program. For simplicity, only typical output and major interfaces have been identified in this chart; the PEP covers the remaining phases of the LFV program. Related activities have been organized into the basic modules identified below:

1. Requirements definition

2. Planning and control

3. Design and integration (includes change control)

4. Verification (includes test)

5. Operations

Modules 1 and 2 cover activities conducted during the Phase B contract. Phase C will include the expansion of activities in modules 1 and 2, and initiation of activities in module 3 up to and including the preliminary design review. Phase D will include the completion of activities in modules 3 and 5. Verification (module 4) will be conducted throughout Phases C and D of the LFV program.

1. Requirements Definition:

   Analyze Program Functions - Establish the approach for effective integration of engineering effort in developing, testing, supporting, and maintaining the system.

   Analyze System Functions - Portray graphically and sequentially all detailed functions that must be satisfied by system elements to meet total system requirements. Select and investigate alternative functions which offer significant benefit in terms of time, cost, and performance.

Space Division
North American Rockwell

INITIAL DRAFT: 6-10-69

NOTES:

1. SOLID RECTANGULAR BOXES ENCOMPASS FUNCTIONS OF THE PROGRAM ENGINEERING PROCESS.
2. OPEN RECTANGULAR BOXES REFER TO INTERFACES WITH OTHER SD MANAGEMENT SYSTEMS
3. THE SYMBOL (A) INDICATES AN INTERFACE WITH THE PERFORMANCE EVALUATION MEASUREMENT VERIFICATION FUNCTION SHOWN.
4. THE SYMBOL (B) INDICATES INTERFACES WITH CHANGE CONTROL FOR:
   - (B1) PROGRAM/SYSTEM SPECIFICATION
   - (B2) CEI DETAIL SPECIFICATION PART I
   - (B3) CEI DETAIL SPECIFICATION PART II & DRAWINGS
5. PRODUCTS OF THE PEP FUNCTIONS INCLUDE, BUT ARE NOT LIMITED TO THOSE SHOWN.
6. THE REVIEW FUNCTIONS, I.E., PROGRAM REQUIREMENTS REVIEWS, SYSTEM DESIGN REVIEW, PRELIMINARY DESIGN REVIEW, CRITICAL DESIGN REVIEW & FACI ARE A PART OF VERIFICATION.

Figure 5. LFV Program Engineering Process

Analyze Program Requirements - Identify the requirements necessary to establish the manner in which company resources and experience will be applied to satisfy the objectives and tasks in the statements of work. Identify control baselines and ground rules necessary to provide efficient management of the system design, development, and operational support programs. Products: system engineering documentation (requirements allocation sheets, timelines, optimization reports, schematics, design sheets, etc.), preliminary development specifications.

Develop Facilities Requirements - For use by an architectural and engineering organization to design and develop system facilities. Products: system engineering documentation, facilities plan, preliminary development specifications, and facility perspectives.

Develop Maintenance and Training Requirements - Identify those requirements to be satisfied by a combination of system elements. Obtain parameters of design, design constraints, and system effectiveness factors to eliminate nonattainable system design configurations, and logistics support concepts. Products: logistics requirements system engineering documentation.

Develop Site Activiation Requirements - Identify those requirements to be satisfied by a combination of system elements. Obtain parameters of design, design constraints, and system effectiveness factors. Eliminate nonattainable system design configurations and activation operations concepts. Products: activation requirements system engineering documentation.

Develop System Test Requirements - Establish plans for test operations to identify design requirements for end items, personnel, and procedural data in support of such operations. Products: test operations plan (development, acceptance, system checkout, etc.) and test support requirements system engineering documentation.

Accomplish Preliminary Design - Support the determination of an approach to system design. Support optimization studies. Support establishment of the initial system requirements baseline. Products: layouts, logic diagrams, configurations, model drawings, preliminary development specifications, equipment procurement specifications, and experimental data.

Select System End Items - Identify those system elements (equipment) for which specific requirements were established by the system engineering process to support the system functions of mission operations, logistics, activation, and test. Products: end item equipment lists (prime, critical, noncomplex, facility, computer program, and inventory equipment).

Integrate System Requirements - Identify and control interface requirements. Identify feedback changes to operations functions, design requirements for the operations functions, and to the system specification. Establish compatibility between system plans. The preliminary system specification prepared during Phase B will be expanded during Phase C, defining overall requirements and providing a basis for subsequent design efforts. The preliminary specification tree will be expanded to show relationships of all program elements. Products: inputs to system specification, specification tree, system plans, system definition handbook, equipment utilization document, and development specifications.

2. Planning and Control:

Plan Engineering Programs - Identify the tasks and align them to program milestones and production schedules. Provide the detail planning that contributes to updating and further defining the master schedule. Provide inputs to the program management networks so that the networks accurately reflect program planning on a schedules and cost estimates basis. Products: system engineering, design engineering, test engineering, and logistics engineering functions will each provide planning, including schedules, budget breakdown, and work packages.

Integrate Engineering Planning - Establish compatibility and consistency between schedules, budget breakdowns, and work packages. Provide an adequate and clearly defined interface with the program planning and control function. Products: engineering development plan and support to the following non-engineering program management plans: facilities, materials, test operations, and manufacturing.

Assess Engineering Cost and Schedule Positions - Determine current positions which, when compared to planned positions, will provide cost and schedule status. Provide cost and schedule position information that can be used as a basis for effective corrective action, if required. Products: engineering cost and schedule status, engineering recommendations for corrective action. (Note: This is a continuous effort which is performed throughout the engineering life of the program.)

3. Design and Integration:

Accomplish Preliminary Detail Design - Translate "design-to" requirements into "build-to" requirements. Identify detailed constraints and additional design requirements applicable to production and maintenance effort. Determine the design approach in order to proceed with more detailed design and to conduct synthesis of alternate approaches that must be studied and evaluated. Design optimization studies will include such overall items as packaging optimization (LM stowage) versus landing criteria and center-of-gravity height and detailed optimizations, such as throttle control position and type for pressure-suited operations. Optimization studies will be selected to concentrate engineering resources at areas of highest potential program benefit. This will include such factors as (1) possibilities of increasing technical performance or reducing total program costs, (2) criticality of mission success, (3) technical risks, and (4) unique problems. Products: logic diagrams, layouts, schematics, drawings for breadboards, mockups, models.

Develop Detail Facility Requirements - Provide the data for facility system engineering. Integrate facility design requirements into facility end items. Identify requirements for real property installed equipment. Identify facility interfaces with other system elements or other systems. Products: system engineering documentation, expanded facility development specifications, diagrams, schematics, layouts.

Develop Detail Test Support Requirements - Identify facilities, equipment, personnel, and procedural data necessary to conduct specified tests. Determine contractor capability for handling specified test programs (in-house versus subcontract). Products: inputs to test plans, detail test support requirements documentation.

Establish Interface Control Requirements - Determine the basis for negotiating interface responsibilities. Identify related interface requirements pertaining to cost and schedule controls. Identify requirements subject to coordination between and concurrence by each of those responsible for the interfacing items. Products: interface control assignment list, inputs to work breakdown structure and program management networks, system engineering documentation.

Develop Detail Maintenance Requirements - Assure that maintenance implications are considered in depth prior to additional preliminary design of operations equipment and facilities. Identify additional requirements for facilities, equipment, personnel, and procedural data. Products: system engineering documentation, preliminary development specifications for equipment.

Integrate Preliminary Detail Design - Further define interface requirements. Identify feedback changes to related design requirements. Establish design approach consistency. Products: inputs to system specification, development, specifications, system definition handbook, specification tree, and drawing tree.

Establish Interface Control - Assure physical, functional, and procedural compatibility between interfacing equipment/facilities. Establish customer/contractor/associate contractor responsibilities for external interfaces. Establish organizational responsibilities for internal interfaces. Requirements for interface control will be identified and transmitted to NASA and coordinated as required so that decisions in these areas will not be performed unilaterally. Products: approved interface control drawings.

Accomplish Detail Design - Create the configurations that satisfy the design-to requirements to derive the design solutions in accordance with the approved design approach resulting from PDR's. Establish detail descriptions of computer programs. Products: Drawings, preliminary product specifications, procurement specifications, detail development test requirements, acceptance test specifications, test results evaluation, etc.

Accomplish Maintenance and Training Support Program Design - Define in detail the logistics operations which must satisfy system requirements. Establish training curricula that will assure personnel skill required. Establish spares selection criteria. Obtain solutions to supply, I&C, transport, packaging, and storage requirements. Products: Training courses, procedures, tech. manuals and handbooks.

Integrate Detail Design - Assure compatibility between and within equipment end items. Identify additional feedback changes to system functions and design requirements. Further refine interface definition. Derive maximum benefits from development testing. Products: inputs to system specification, specification tree, drawing tree, WBS, PMN, etc.

Complete Design for Production Release - Provide 100 percent release of initial design configurations. Establish the initial build-to baseline for individual end items. Products: drawings and specifications.

4. Verification:

Conduct Engineering Breadboard and Mockup Operations - Verify design solutions. Establish clearances and preclude interferences. Product: verified designs and equipment installation locations.

Accomplish Development Test Programs - Verify the structural integrity of designs under static and dynamic conditions. Assure that qualification requirements are satisfied. Assure achievement of reliability goals. Determine suitability of design configurations physically, functionally, and procedurally. Verify selected materials and processes. Products: test procedures, test reports, expanded test plan.

Conduct Technical Performance Measurement - Technical performance measurement (TPM) is the process by which SD identifies problem areas before impact can be detected in cost and schedule status reports. Sensitive indicator parameters will be selected to detect problems early in a program. TPM will be coupled with cost and schedule planning to provide effective avoidance of costs due to unforeseen problems. This process consists of planning, measuring, evaluating, and reporting technical performance status, and includes the following features:

1. Selection of technical performance parameters
2. Prediction of target values for selected parameters
3. Scheduled measurement or estimation of selected parameters
4. Identification of variances from target values
5. Prediction of variance impact on contract completion performance.
6. Provision of management visibility impact on contract completion performance.

The TPM process is used to identify technical problem areas which have contract, cost, schedule, or system performance impact. TPM predicts operational performance well in advance of ground or flight tests, by comparing estimated or measured performance of selected WBS elements to predicted performance. Products: TPM list, TPM parameters, TPM reports.

Conduct System Performance Evaluation - Evaluate variations between system performance requirements and actual performance measurements to determine potential impact on system operations, capabilities, schedules, and cost. Products: system performance evaluation reports.

Conduct Product Performance Evaluation - Evaluate variations between end item or component performance requirements and actual performance measurements to determine potential impact on product operation, capability, schedule, and cost. Products: product performance evaluation reports.

Conduct Mission Effectiveness Evaluation - Provide the optimum combination of system elements to meet the mission objectives and support requirements in terms of system effectiveness, schedule, and life cycle cost. Obtain decisions which have as their objective the optimum balance among system effectiveness, schedule, and total life cycle cost rather than undue engineering sophistication. Conduct such analyses or trade studies throughout the system engineering process support to system development and operation. Products: optimization reports, design decisions.

5. Operations:

Support Logistic and Activation Operations - Provide contractor assistance during transport and installation of equipment, and checkout of equipment and procedural data. Products: technical and administrative feedback of changes to contractual specifications and drawings, mod kit installation, manuals and handbook revisions, etc.

Support System Operations - Provide contractor assistance during system mission operations.

6. Subsidiary Activities:

The engineering development plan, when fully expanded during Phase C, will include coverage of the following, and possibly additional, essential subsidiary activities:

Reliability Program Plan. The reliability program plan will be the master planning and control document for the reliability program for development of the LFV. It will include a detailed, time-phased description of all tasks to be performed and the procedures for implementing, monitoring, and controlling these tasks. The document will follow the outline and intent of NPC 250-1 and comply with specific modifications as directed by the customer. The document, upon approval by the customer, will be contractual. The plan will include the following significant tasks, as applicable:

(1) Reliability program management

(1.1) Document reliability program

(1.2) Monitor and control reliability program

(2) Reliability analysis

(2.1) Perform quantitative analyses

(2.2) Update and maintain in current status the predictive analyses for mission success and crew/vehicle safety

(2.3) Prepare, update, and maintain in current status the failure mode and effects analysis (FMEA)

(2.4) Provide data for and support design reviews

(2.5) Provide a central source for parts and materials characteristics and specifications

(2.6) Review all drawings and monitor drawing changes for reliability implications.

(3) Specification evaluation - Review, contribute to, and approve procurement, ICD, end-item, and configuration specifications.

(4) Test Planning

(4.1) Support preparation of and review test plans, specifications, and procedures.

(4.2) Perform reliability assessment for specified parts and materials based on available test data.

(4.3) Determine additional test requirements necessary for completion of qualification and acceptance.

(4.4) Contribute to a qualified equipment status list.

(5) Supplier reliability program management

(5.1) Specify supplier reliability and reporting requirements.

(5.2) Review incoming supplier reliability and design documents for compliance with specifications.

(6) Failure analysis - Analyze and recommend corrective action, where indicated, for all procedure, part, and material failures during test.

(7) Reliability program reviews

(7.1) Coordinate with NASA/MSC to establish content and timing of reliability reviews.

(7.2) Perform reliability program reviews.

Maintenance/Maintainability

A maintenance concept will establish the detailed techniques and procedures that will provide maintenance support for the system during test and launch operations or its operational use. Lunar surface tasks necessary to ensure normal system readiness will include refueling and checkout operations. These functions will be a source of design requirements for effective equipment maintainability and identify procedures to be used to demonstrate that maintainability requirements have been achieved.

System Safety Plan

This plan will identify the tasks to be performed throughout the LFV program to assure the application of system safety principles and describe methods and techniques to be used to attain the objectives. The plan will follow the guidelines set forth in the contract statement of work, NR policies, procedures, manuals, handbooks, and customer directives. The effort will be closely coordinated with the reliability program and design verification. System safety will be a prime consideration in all requirements, design, and product reviews, as well as in all performance evaluations, where applicable. Major tasks to be performed include (1) establishment of system safety program requirements; (2) system safety hazards analyses; (3) identification of high-risk areas (hardware, systems, procedures, criticality, etc.); (4) ensuring associate/subcontractor system safety; (5) system safety training; and (6) system safety monitoring.

Human Engineering

The Engineering development plan will provide a guide relative to the concepts, techniques, procedures, and technical process required to assure adequate consideration of the integration of the crews and human data into all phases of design, checkout, support, and operations as may be required in the development of the vehicle subsystems.

Mockups

The engineering development plan will outline the contractor's intended use of mockups for the purposes of (1) verification of design configurations, interface considerations, equipment installation locations, and clearances; (2) aid in the manufacture of tubing, cable harnesses, etc.; (3) verification of human factors design criteria; and (4) supporting design reviews by customer personnel.

Electromagnetic Interference Control

If required as a deliverable item of the contract, a detailed description of the EMI control program will be submitted. Test facilities, equipment, and procedures will be described.

Consolidated Special Test Equipment (STE)

The primary objective will be to provide for identification, acquisition, use, control, and evaluation of STE required for the program. STE will be used to support manufacturing operations, laboratory test operations, and field test operations in unique situations where the use of ground support equipment (GSE) is not applicable.

Lunar/Ground Operations

The objective is to provide functional flow diagrams and associated functional descriptions to illustrate the planned mission support operations. Included are the activities of activation, supply, transportation, installation, checkout, and servicing. The engineering development plan will specify the sequence of operational functions to be performed before and after the earth launch operations and thus provide a source of requirements for lunar/ground support equipment and other system elements.

Lunar/Ground Support Equipment (LSE/GSE)

Support equipment provided to satisfy ground and lunar surface operations requirements will be provided on a cost-effectiveness basis and significant optimization studies will be conducted with the criteria for optimization being the best combinations of system effectiveness and total life span cost of the system. Minimum physical characteristics will be a criterion for lunar surface equipment.

Mission Operations

Analysis of the operations of a planned mission will be the basis for developing detailed requirements for mission functions. Such requirements, in turn, will lead to the establishment of design requirements for aerospace vehicle configurations.

Schedule and Major Milestones

Significant engineering milestones are presented on the program development schedule. These include the following reviews:

1. Program requirements review (support)
2. System design review (prime)
3. Preliminary design review (prime)
4. Critical design review (prime)
5. First article configuration inspection (support)
6. Flight readiness reviews (support)

Other milestones are design freeze date, 100 percent initial drawing release date, 100 percent initial acceptance test specification release date, GSE/LSE requirements submittal, and GFP requirements submittal.

Plan Interfaces

The system engineering approach is based on the system specification, the specification tree, the work breakdown structure, and applicable NASA directives. The engineering development plan, as developed, is compatible with other contractor program plans and is a major element of the program master plan. Interface between the program plans will be developed in detail during the Phase C portion of the program and reflected in the expanded plans.

Customer Liaison

Engineering interfaces with customer representatives will occur as necessary to support the following requirements:

Interpretation of contract requirements	(occasional)
Review of system requirements	(occasional)
Review of system design	(scheduled)
Review of preliminary design approach	(scheduled) (PDR)
Review of detail design	(scheduled) (CDR)
Technical briefings	(occasional)
Technical documentation approval	(scheduled data submittal)
Submittal of GFP requirements	(scheduled)
GSE/LSE requirements verification	(scheduled)

Documentation

The program engineering process has been developed at Space Division to provide a complete response to customer requirements at the lowest overall costs, including costs of the program engineering process. This requires careful balance of effort to expend the proper amount of resources during Phase C in order to realize minimum development, production, operational, and maintenance costs later in the program.

In tailoring the SD program engineering process to the LFV Program for the Phase C and D effort, a major consideration will be its cost-effective application. Therefore, only selective documentation will be prepared. However, adequate documentation will be provided to clearly record engineering decisions so that engineering development can proceed without repetition. In addition, traceability of SD design solutions back to basic NASA requirements will be provided.

Information will be recorded and circulated throughout the program in a system definition handbook bringing together the results of all program activities. This handbook will be a single, authoritative source of data for all design and analysis groups, controlled by System Engineering. Three major areas of data will be included: (1) basic system and program design criteria, ground rules, envelopes, and constraints; (2) system-level analyses including functional flow block diagrams and system schematic block diagrams; and (3) decisions and agreements affecting system configuration such as optimization results and potential interface problems. Data will be incorporated through the most economical, expedient methods that are suitable. The book will be maintained as a reference document for requirement sources, after being superseded by specifications.

The basic data elements produced during requirements evolution will be prepared in the most economical, legible, commercial form and controlled by System Engineering. For example, flow diagrams will be prepared as indentured lists by typewriter unless they are so complicated the information can only be presented graphically. Duplication of effort will be avoided by discontinuing production and/or maintenance of documents when subsequent documents are prepared. Closeout of original documents will include reference to those developed later.

MANUFACTURING PLAN

The manufacturing plan for the lunar flying vehicle, lunar support equipment (LSE), ground support equipment (GSE), and nondeliverable support equipment is composed of six sections which describe the system and operations by which NR will prepare for, produce, install, and check out the LFV's, test articles, and support equipment.

Each of the sections listed below which comprise the plan has its own introduction or summary to allow for each reference to particular areas of interest.

1. LFV manufacturing summary
2. LFV and test article fabrication
3. Support equipment fabrication
4. Manufacturing engineering
5. Production control
6. Program coordination

The operation's baseline discussed herein is predicated on LFV configuration data prevailing at the completion of Phase B. Methods and processes described, although specifically attuned to this baseline, will remain generally applicable to the overall program regardless of ensuing design changes. Specific changes affecting the program, however, will be incorporated into internal plans and documentation as prescribed by normal business system disciplines.

LFV Manufacturing Summary

Manufacturing Organization

Management of LFV manufacturing activities will be administrated through a program-type of organization with the LFV Manufacturing Manager reporting to the LFV Program Manager, for program direction. He will be responsible for coordinating all aspects of the manufacturing effort. Figures 6 and 7 represent the manufacturing organization structure.

The experience gained by NR on the Apollo and AAP CSM, and Saturn S-II programs has provided a high degree of manufacturing technology and mechanical excellence which will be utilized in all facets of developing the manufacturing plan and implementing the LFV Phase C and D program.

Manufacturing Responsibilities

Manufacturing, under the direction of the LFV Manufacturing Manager, will be responsible for the fabrication, assembly, and checkout of lunar flying vehicles, lunar support equipment, ground support equipment, special test equipment and parts protection, and material handling equipment. This function will also be responsible for developing and maintaining master and detail schedules, control procedures, resource planning of manufacturing costs and budgetary allocations, and for the development and fabrication of tooling and special test equipment requirements. To assure that costs, schedule, and product quality objectives are satisfied, the LFV Manufacturing Manager will direct all phases of the manufacturing operation utilizing existing management systems described in the Production Control section.

LFV and Test Article Fabrication

This section contains brief descriptions of the LFV requirements and the fabrication and testing methods, followed by a tentative manufacturing flow plan (Figure 8). A preliminary manufacturing breakdown (Figure 9), depicts the LFV fabrication sequence.

Detail fabrication, consisting of sheet metal, machined, and plastic parts will be accomplished within established shop departments, utilizing conventional shop practices with tooling requirements kept to a minimum. The basic LFV structural assemblies consist of a landing support structure of sheet metal and machined parts riveted and bolted into a cruciform assembly. The platforms are of sheet metal and machine parts, riveted with brackets and tracks for mounting the cargo decks, translating seat assembly, engines, and the helium, fuel, and oxider tankage. Structural subassemblies will be fabricated in the existing precision assembly shop. Assembly fit-check of the structural subassemblies will be performed prior to final assembly of subsystems.

System installations, to be accomplished in a clean room environmental area, will consist of the installation of the attenuators, propulsion subsystem, power subsystem, stability and control subsystem, and the display controls. Tubing and electrical installation will be performed,

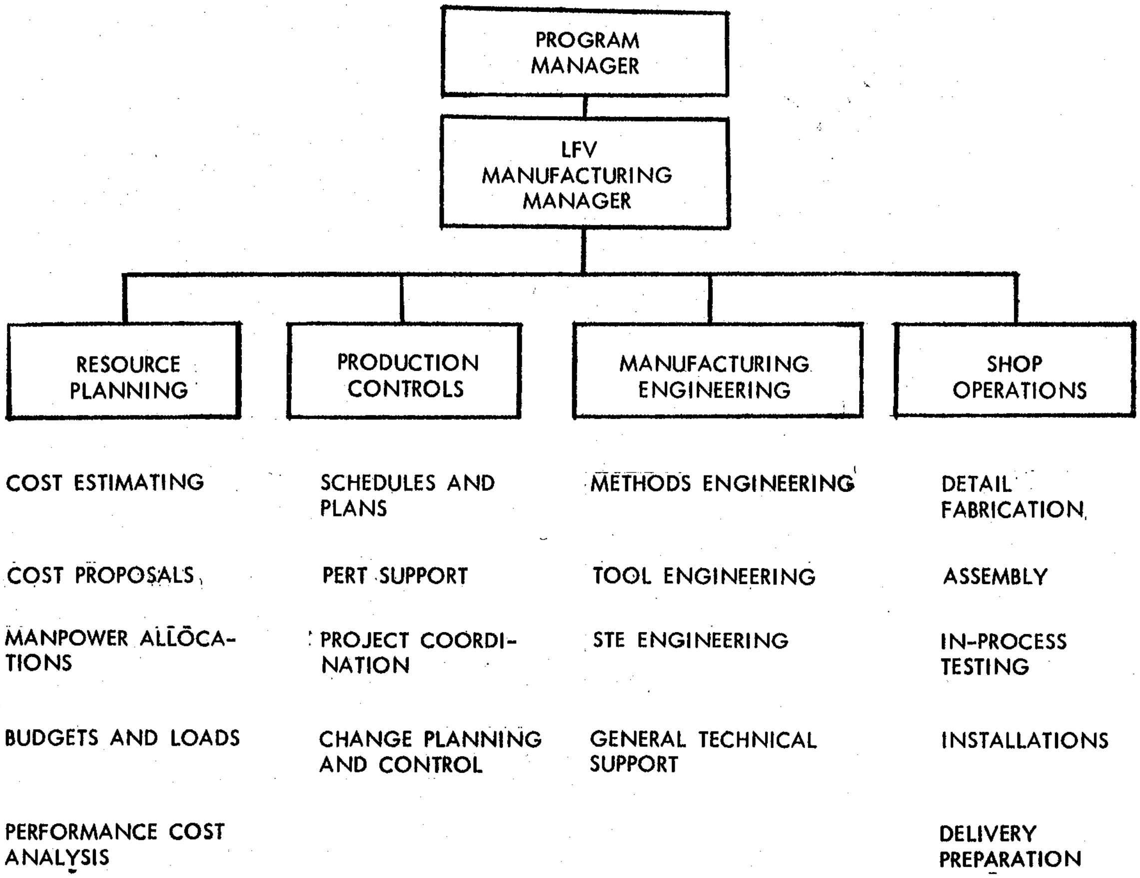


Figure 6. LFV Manufacturing Organizational Structure

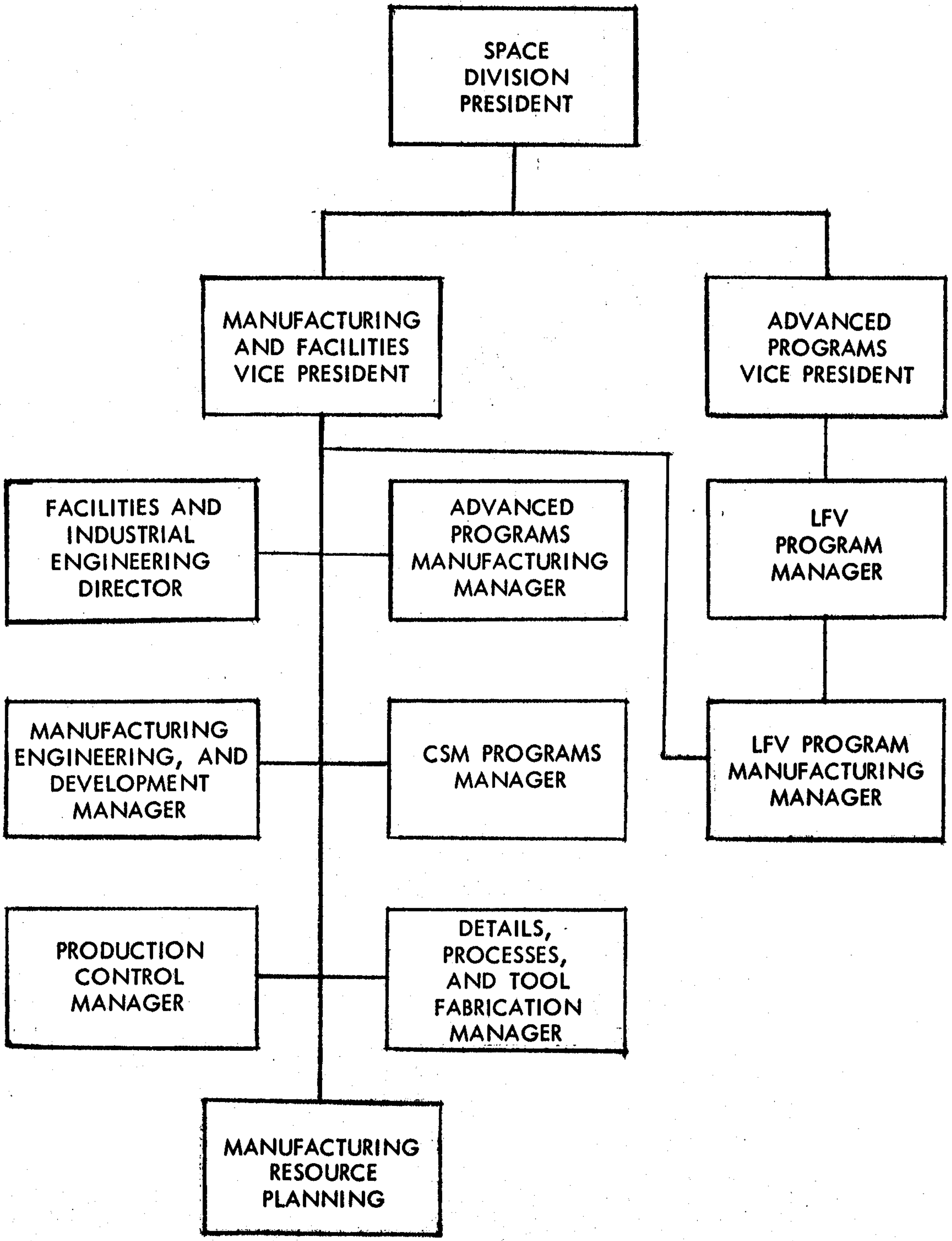


Figure 7. LFV Manufacturing Reporting Channels

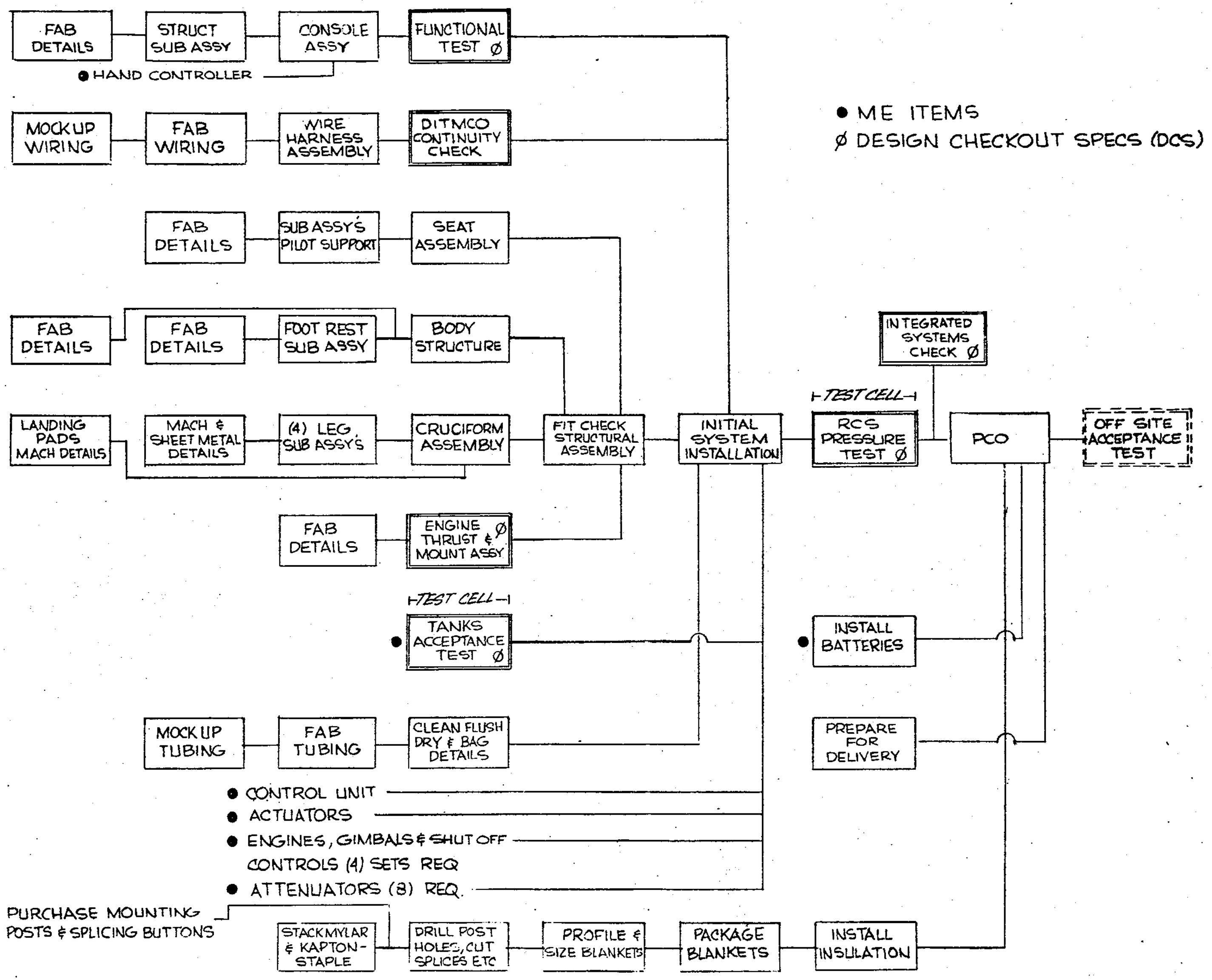


Figure 8. LFV Manufacturing Flow Logic Plan

Figure 9. LFV Manufacturing Breakdown

utilizing existing equipment and technology derived from the Apollo CSM, to support LFV requirements as applicable. Manufacturing testing will be conducted progressively to design checkout specifications (DCS's) utilizing existing, modified, and/or new special test equipment factory servicing and factory checkout equipment to verify electrical, mechanical, and electromechanical subsystems and assemblies.

Test Article Fabrication

Test article hardware will be fabricated by Manufacturing and will consist of a LFV landing test vehicle, a thermal test vehicle, a structural test vehicle, and a propulsion/SCS ground test vehicle. These will consist of detail parts and structural assemblies. Normal shop techniques and facilities will be used to fabricate the test hardware. The LFV structural tools will be scheduled earlier than the spacecraft need dates to support test articles. Test article definition will be expanded during the Phase C preparation of the manufacturing plan.

Support Equipment Fabrication

This section of the plan includes a brief description of the support equipment to be provided. The nondeliverable support equipment for LFV fabrication consists of special tooling, special test equipment, and material handling and parts protection equipment. The deliverable support equipment consists of lunar support equipment and ground support equipment.

Nondeliverable Support Equipment

Nondeliverable support equipment is described in the following paragraphs.

Special Tooling. Special tooling that will be fabricated consists of templates, detail tools, assembly tools, simulators, and tubular joining tools. Tooling lists, schedules, concepts, and tooling bar charts for the special tooling will be developed during Phases C and D of the LFV program.

Special Test Equipment (STE). Manufacturing will use NR/SD tool and gage crib test equipment, existing STE, designed and fabricated for the Apollo CSM program and additional test equipment to be programmed by STE Engineering in Phase C of the LFV program. The STE design as well as the fabrication is scheduled by model number. Examples of special test equipment are factory servicing and factory checkout equipment used to verify electrical, mechanical, and electromechanical assemblies and systems.

Material Handling/Parts Protection (MH/PP). This equipment includes handling slings, dollies, work platforms, racks, and protection devices required to efficiently handle and protect the LFV products through all phases of fabrication, assembly, and test operations. Facilities and Industrial Engineering is responsible for determination of requirements and design of MH/PP equipment. Fabrication will be accomplished utilizing normal shop procedures and facilities.

Deliverable Support Equipment.

The LSE and GSE are delivered as contractual end items and are required to maintain the functional status of a system, end item, or components. LSE and GSE will consist of the following-type items to support LFV.

Checkout equipment which verifies the functional integrity and flight readiness of spacecraft systems.

Auxiliary equipment which supplements the functions of other major items of GSE.

Servicing equipment which distributes, meters, monitors, controls, stores, and disposes liquid and gases between the spacecraft, other items of GSE, and facility supply sources.

Handling equipment which provides transport, access, protection, and weight and balance capabilities.

Manufacturing fabrication and assembly of deliverable support equipment will be performed within normal NR operating procedure and existing facilities.

A more precise definition of individual items will be made to support the manufacturing plan in Phase C of the program.

Manufacturing Engineering

The Manufacturing Engineering organization performs functions representing manufacturing producibility, tool engineering, special test equipment engineering, manufacturing methods, manufacturing order planning, shop contact and technical change analysis. These functions provide technical support to manufacturing departments responsible for the fabrication, installation and testing of LFV, LSE, and GSE hardware.

Manufacturing Producibility

During Phase C design development and Phase D fabrication, Manufacturing Engineering personnel will serve as producibility consultants to

LFV Design Engineering to provide analysis of designs from a fabrication and tooling feasibility viewpoint and to recommend the optimum practical approach on dimensioning, machining, forming, processing, and subsystems installation and checkout verification to facilitate fabrication operations.

Tool Engineering

Preprogramming and tool design are the functions of Tool Engineering.

Preprogramming

This function entails several advance activities, performed by Manufacturing engineers, in the development of manufacturing flow logic plans, manufacturing breakdowns, tool concepts, tool lists, tooling bar charts, tooling schedules, and preliminary hours estimates of special tooling to support LFV, LSE, and GSE.

Tool Design

The basic purpose of a tool design function is to assure the dimensional integrity of the deliverable hardware imposed by quality control requirements, and to support the selected fabrication methods with the proper tooling. Tool design, which is part of Manufacturing Engineering, will design all new design type of tooling required to support LFV, GSE, and LSE. Tooling that will be designed for the LFV program will be primarily in support of structural fabrication and subsystems.

STE Engineering

Manufacturing Engineering performs subsystem analysis to establish test sequence logic, determines available sources of test equipment, and provides Manufacturing with test logic flow plans. Based on the test logic, flow plan drawings and engineering requirements for design checkout specifications (DCS) are determined.

STE Design

Manufacturing Engineering will design new and modify existing STE designs of factory servicing and factory checkout special test equipment to verify LFV electrical, mechanical, and electromechanical assemblies and systems.

Manufacturing Methods

Manufacturing Engineering personnel will provide manufacturing with a working knowledge of new and existing fabrication techniques and processes and instruct shop personnel in the special and proper use of production aids and serve in a consultant capacity on problem areas in all phases of systems tooling.

Manufacturing Order Planning

Production planning and tool planning are functions performed by Manufacturing Planning personnel who interpret engineering orders and drawings and translate them into individual production work orders. Detail parts, assembly, and system installation planning of production operations are established with considerations given to schedule, manufacturing techniques and processes, system installation, and test requirements. Tool planning function is responsible for the preparation, issuance, and maintenance of all tool orders in support of the LFV program. Serialized tool identification numbers are assigned to all special tooling to facilitate location and inventory control of tools.

Shop Contact

Manufacturing Engineering personnel are involved in resolving production in-process and fit and function problems normally associated with techniques and processes required to produce an acceptable part, subassembly, or system assembly.

Production Control

The methods for regulating manufacturing programming activities in accordance with LFV, LSE, and GSE objectives are described briefly in this section of the plan.

Policy and Procedures

Systems are available to furnish management and the customer with accurate data and program visibility and will be described in the finalized plan. Fabrication assembly and inspection record (FAIR) production planning tickets, manufacturing data retrieval (MADRE), and production order location and report system (POLAR) documentation will be implemented to support the LFV program. Utilizing these control systems, management will monitor fabrication activities and control departmental loads. Production problems can, therefore, be rapidly identified and corrective action initiated by the responsible personnel.

Program/Scheduling

Master programming/scheduling charts depicting the long leadtime procurement requirements will be provided in the plan. At the onset of the LFV program, during Phase C, a master development schedule will be established, based on an analysis of engineering design development information, to depict a completely coordinated plan for the fabrication of mockups, test articles, and flight vehicles. A tentative test article and first ship schedule is shown in Figure 10.

Plans Interface

Interface coordination with the other LFV engineering, facilities, material, quality assurance, and test operations plans will be conducted as required to ensure compatibility of the fabrication effort. Examples are recommendations of facility requirements utilizing existing equipment wherever possible. Identification of long lead procurement requirements and defining scheduling interface with material to ensure compliance of concise program need dates for purchased components will be done.

Customer/Subcontractor Liaison

The LFV customer and subcontractor liaison requirements will be established by requests of Program Management and Material to Manufacturing and will be defined in Phase C of the Manufacturing plan. A typical example would be the coordination of the engine/gimbal mounting holes to ensure compatibility of installation.

TEST PLAN

Purpose

This test plan outlines the overall test program for the one-man lunar flying vehicle. This test program is intended to ensure the timely delivery of a thoroughly tested, highly reliable space vehicle.

Scope

Presented in this test plan are the significant tests to be accomplished during the acquisition phase of an LFV Program. The plan is intended to provide the gross framework from which more definitive test requirements are established, thereby leading to development of detailed development, qualification, and acceptance test plans and schedules. Major milestones and gross test spans have been identified in the program development schedule to depict the overall test phasing and time-relationship with other program activities.

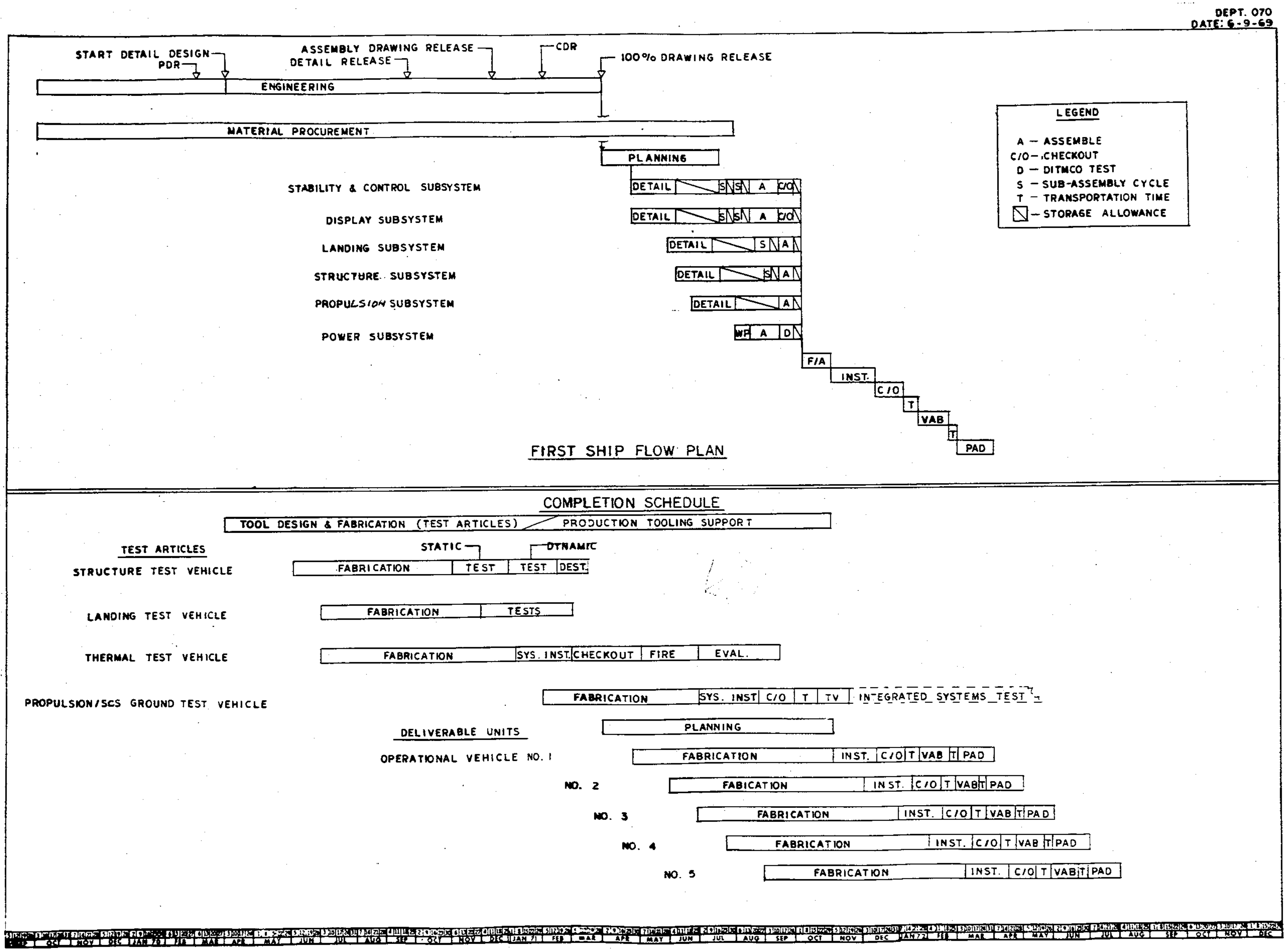


Figure 10. One-Man LFV Tentative First-Ship Manufacturing Flow Plan and Completion Schedule

Test Approach

The testing program designed for the LFV is based on satisfying, in an orderly progression of tests, all requirements established for development, qualification, and acceptance. As a result, maximum assurance and confidence are provided as to the capabilities of the vehicle to perform in accordance with mission criteria. The sequencing of the test articles and individual tests is intended to satisfy two major objectives. The first is to provide sufficient time for feedback of anomalies or improvements discovered during early tests into the design of the operational vehicle. Secondly, an attempt is made to simulate, as closely as practicable, the environmental conditions that the vehicle will be subjected to during the actual mission operation.

The testing described in this test plan is divided into three main categories: development, qualification, and acceptance.

Developmental Tests

Developmental tests are defined as those tests performed to informal procedures and intended to empirically optimize or verify the design. These tests provide an early indication of problem areas which are difficult to adequately assess by analysis only.

Qualification Tests

Qualification tests establish the validity of the design to meet the functional performance requirements over the full range of the anticipated environments. Actual test conditions are usually more severe than the predicted environment. This provides assurance that design weaknesses will be disclosed as well as providing a performance margin to allow for manufacturing tolerances and uncertainties in the predicted environments. All tests will be performed in accordance with previously approved procedures and shall be adequately documented.

Acceptance Tests

Acceptance tests are those tests conducted to disclose workmanship defects and manufacturing tolerance accumulation to an undesirable value. The acceptance tests are conducted in a progressive manner as the vehicle is assembled. This ensures a completed article capable of performing all of the mission requirements in the predicted environment. These tests are performed on all flight and spares hardware according to previously approved test plans and procedures.

Component/Subsystem Level Tests

Most of the components and subsystems are purchased parts and wnerever possible will be previously space-qualified items. This will reduce the development and qualification testing to a minimum.

Vehicle Level Tests

Development testing at the vehicle level will be limited to those parameters that cannot be effectively accomplished at the subsystem or component level. Qualification testing on a full flight-configured vehicle will include all of the environments that the vehicle will experience to the extent that they can be simulated. The stress levels for all load tests will be in excess of predicted flight loads wherever possible. Acceptance testing at the total vehicle level will include exposure to selected environments but stress levels will not exceed predicted flight levels.

Major Test Articles

Structural Test Vehicle

This vehicle will include the basic body/frame structure, the load pans, pedestal, and restraints. This structure will be built in the same production facilities and to the same tolerances as the flight vehicle structure. For the static tests, center-of-gravity locations of significant mass components will be duplicated in test fixtures, and loads will be applied to the structure through the component attach points.

This test is intended to demonstrate the structural integrity of the primary load-carrying structure during the application of sustained loads as experienced during the various phases of the mission.

The vehicle structure will be instrumented at critical locations with strain gages and deflection transducers. Load, strain, and deflection data will be recorded on equipment providing digital display for monitoring as test loads are applied, plus digital printout and IBM compatible punched tape for data reduction purposes.

Loads will be applied by means of hydraulic cylinders through tension or shear pads, and at hard points designed for component attachment. The dead weight of loading fixtures and whiffletree linkages will be counterbalanced or otherwise compensated for.

Visual inspection will follow each test condition to determine whether any deformation or other signs of yielding of the structural elements can be detected.

Dynamic tests will be conducted with dummy masses substituted for significant components and subsystems which will be installed on the test article to evaluate their dynamic responses and corresponding effect on the vehicle structure.

There are two primary objectives to be met in this series of tests. The first is to verify the structural integrity of the basic structure used to support components, subsystem, and systems when exposed to the vehicle dynamic environment. Secondly, it is imperative to determine the vibration levels that each component, subsystem, or system is subjected to. This information will then be compared with the design requirements imposed on the components and subsystems. The component/subsystem requirements may then be modified or the vehicle structure modified, if required.

The structure will be instrumented with accelerometers and strain gages located at strategic structural locations, and at the mounting interfaces between significant components and the mounting platform. All components will be mounted to structure in the same manner that is intended for the flight vehicle.

Landing Test Vehicle

The impact of landing an LFV on the lunar surface after an exploration sortie will be simulated. Tests employing critical decelerations, impact attitudes and anticipated terrain features will demonstrate the capability of the landing gear to absorb the impact load and maintain vehicle orientation. Sink rates and lunar terrain will be simulated with vehicle weights varying from fully loaded landings, similar to immediate return after takeoff, and fuel depleted landings with and without experiment payloads. The landing test vehicle will include flight type structure (i.e., landing pads, leg frame and attenuators, etc.), and will be brought up to values simulating LFV flight weight and inertia effects.

Thermal Test Vehicle

The thermal/vacuum vehicle is an operational configuration complete with lunar refueling and preflight checkout equipment (lunar support equipment). LM/LFV/astronaut interface and functional performance of all systems, exclusive of live engine firings, will be demonstrated under vacuum conditions. The LFV will be qualified for the extremes of thermal-vacuum environments anticipated during its mission on the lunar surface.

Mockup No. 1

This mockup will be essentially nonfunctional and will be utilized by engineering during the early phases of the program to assess the impact of configuration changes, establish equipment location, and wiring and plumbing installation.

Mockup No. 2 - House Vehicle

This vehicle will be utilized to conduct engineering tests and engineering reviews. Subsystems will not be fully qualified flight hardware, but rather, of a quality adequate for engineering tests. No engine firings will be attempted with this vehicle. Design changes occurring during the program will be incorporated in this vehicle.

Propulsion/SCS Ground Test Vehicle

This vehicle will be essentially a qualified flight vehicle. It will be utilized to conduct integrated system tests and actual firing of the rocket system.

Operational Vehicle Flow

Downey Acceptance Testing

Subsequent to subsystem installation and leak checks, the LFV subsystems will be progressively energized in an accumulative fashion culminating in an integrated systems test (without engine firings) which will demonstrate all systems under ambient conditions. After a review of the test results and the completion of weight and balance and LM simulator mechanical interface verification, the vehicle will be accepted and shipping preparations initiated.

Launch Site Test Operations

A visual receiving inspection will be performed immediately after the receipt of the LFV at the launch site. The suited astronaut, PLSS, and LFV interfaces, including adjustment of harnesses, etc., will be verified. The LFV will then be stowed in the LM and will remain dormant until the LM lands on the lunar surface.

MATERIAL PLAN

This plan has been developed to define the areas of responsibility for the material organization in providing support to Phases C and D of the lunar flying vehicle program. The methods used will follow guidelines developed from experience in material support to the current Apollo and Saturn Programs. System techniques as applicable will be modified and applied to the LFV Program.

This plan will become effective upon receipt of the Phase C contract award for the Lunar Flying Vehicle Program and the plan will remain in effect until completion of Phase D, subject to revision as requirements are defined in the prime contract.

The material organization will be responsible for managing all material requirements for the Lunar Flying Vehicle Program. The procurement responsibility begins with participation in preliminary make-or-buy decisions. Material activity will also include planning for support of initial program requirements, survey and evaluation of potential subcontractors, release of requests for proposals, proposal evaluation, source selection, cost and price analysis, negotiation of subcontracts, placement of purchase orders, obtaining customer approvals as required, and subcontract administration to assure complete program support. Internal controls on warehousing, distribution and traffic activities assure proper and timely material handling.

Following is an expanded definition of each material task required which will assure successful Lunar Flying Vehicle Program support.

Make or Buy

Preliminary make-or-buy decisions decree that the majority of major components required for the lunar flying vehicle will be purchased. Purchased items will include engines, attenuators, computer/gyro system, actuators, hand controllers and fuel/oxidizer tanks.

Precontract Effort

Preliminary statements of work have been forwarded to candidate subcontractors who will provide leadtimes for design/development and production. Supplier information will be used to further refine technical statements of work prior to receipt of the Phases C, D contract award.

Request for Proposals

Request for Proposal packages will be prepared in advance of receipt of the Phase C contract; these will be modified to incorporate changes consistent with the prime contract and issued to candidate subcontractors shortly after contract award. Prime attention will be applied to engine and control system development during the initial part of Phase C. The completion of technical specifications, RFP release, evaluations, and source selection will receive top priority to support these long lead-time items.

Material Planning and Control

Upon release of procurement authorization documents from program engineering, material planning and control will perform an analysis to determine complete program requirements. Purchasing authorization records will be separately maintained by contract number. Available stock will be screened for program usage prior to placing requirements into the procurement cycle. The use of mechanized material requisitions for material deletion will enable constant surveillance of material usage against LFV program requirements.

Material planning and control representatives who attend configuration control and change board meetings will provide this advance information to buying personnel to effect minimized cost and schedule impact on all mandatory changes.

Source Selection

An initial analysis of candidate subcontractors has been accomplished during the Phase B study. This analysis was based on subcontractors related experience and performance on aerospace programs where similar equipment has been developed. Subcontractor surveys will also be performed to further assure production capabilities and review performance on past programs.

The initial step in the final selection of subcontractors will be the transmittal of a formal request for proposal structured to include a detailed statement of work, data requirements, firm program schedules and pricing information to be used for proposal evaluation, negotiation and contract administration. After receipt of candidate subcontractor proposals a final make-or-buy determination will be made based on the most cost effective approach and master program schedule support considerations.

Cost Analysis

All supplier proposals, where appropriate, will be subjected to cost and/or price analysis. Specialists located within the Material department and from other functional departments will assist procurement personnel in proposal evaluation.

Prior to contract negotiations and after cost and price analysis has been accomplished, fact finding meetings will be held, if required, to resolve any questionable items contained in proposals. Verification of cost factors (overhead, burden rate, hourly rates, and availability of government facilities) will be conducted by the NR Internal Audit department or a request for audit verification will be submitted to the cognizant government agency. Upon completion of fact-finding at a subcontractor facility, the procurement team will establish a negotiation base position.

Negotiations

The NR negotiation team will be chaired by an appointed LFV Program buyer. He will be assisted by all functional departments necessary to assure complete compliance to total program requirements. Those departments include engineering, manufacturing, reliability, and data management.

The assigned buyer will conduct negotiations for the company subject to the approval of North American Rockwell management and customer requirements. All negotiated agreements with the subcontractor will become a part of the formal purchase order.

Subcontract Management

Proper subcontract management plays an important part in successfully completing the requirements of any contract. Surveillance of subcontractor performance begins with placement of purchase order and continues until final hardware deliveries and test reports have been submitted and accepted by North American Rockwell. To provide continual subcontract visibility to NR and the customer, NR Manual MR-2 (Management Proposal Requirements) will be a part of each subcontract. This report requires the submittal of biweekly or monthly milestone reports which outline overall program plans, schedules of accomplishment, and actual progress against each separate item of the contract.

Subcontractor documentation controls will also include, contingent upon the criticality of each purchased item, NR's approval of subcontractor's development plans, quality assurance plan, qualification and acceptance test procedures, and test reports.

Also, monthly progress reports will be submitted, summarizing in narrative form work accomplished, problem areas encountered and resolved, and unresolved problem areas including proposed solutions and any other significant developments of interest to North American Rockwell and the customer. The report will be divided into sections that will summarize accomplishments within engineering, material, manufacturing, and quality assurance. In addition, subcontractor performance and controls are accomplished by periodic inspection of work in progress by North American Rockwell quality assurance representatives and buyer visits to the subcontractor's facility, as required. Also, continued contact by phone will be made to obtain verbal progress reports as deemed necessary.

Material program schedules will be established in accordance with the LFV program master development schedule as prepared by program management. Initial emphasis will be placed on the release of formal requests for quotations to provide prompt subcontractor response on all long leadtime items.

Continued liaison will be conducted with engineering and manufacturing throughout the contract to assure agreement and successful accomplishment of all program milestones as required.

Customer Interface

Prior to the award of any purchase order or changes thereto or changes to technical specifications for the Lunar Flying Vehicle Program, approval of the resident customer contracting officer will be obtained. Also subcontract progress reports will be provided as requested.

Warehousing and Traffic

Material has already developed systems for control of materials on small prime contracts to prevent loss of identity in both warehousing and transportation. Warehousing and traffic and transportation facilities currently in use on the Apollo and Saturn Programs will be utilized to store and support packaging and movement of all materials required for the Lunar Flying Vehicle Program.

Plan Revision

Upon receipt of a prime contract, this material plan will be revised to meet additional specific requirements as depicted by the contract terms and conditions.

FACILITIES PLAN

Purpose

The purpose of this document is the establishment of a preliminary plan for the facilities and industrial engineering activity generated by a Phase C and D One-Man Lunar Flying Vehicle Program.

Scope

The scope of activity is limited to:

1. The vehicle described by Contract NAS9-9045

2. Facilities owned or operated by the North American Rockwell Corporation, or as modified by a contract for Phases C and D, primarily the Space Division complex at Downey, California, and the Santa Susana Field Laboratory of the Rocketdyne Division.

The plan assumes the engineering and production space and specialized equipment necessary to this effort will be available for the entire program on a noninterference basis from other company commitments.

The following sections describe the tasks, schedule, major milestones, and the available facilities.

Tasks

The following facilities and industrial engineering tasks are required to support Phases C and D:

Facilities plan
Facilities support for manufacturing and test
Activation of the test and checkout facility
Provide material handling/parts protection equipment
Facilities support for propulsion tests

The scope of these tasks is outlined below.

Facilities Plan

The facilities plan will provide direction for F&IE participation in Phases C and D effort and will assign responsibilities to ensure satisfactory performance. The plan will be complete by the end of the second quarter under contract. It will define existing contractor and Government facilities utilization and the additional facility requirements generated by this program. Analyses and studies will be performed and interfaces with other functional groups established to ensure optimum coverage of all facility needs.

Facilities Support for Manufacturing and Test

This task will integrate F&IE with other functional groups active in program performance. Points of contact will be established and liaison maintained to coordinate activity to eliminate schedule constraints and interface problems. Rearrangement of personnel and equipment to meet specific program needs will be identified and implemented under this task. Activity will include coverage of the administration and engineering offices, the production facilities and laboratory and test facilities as described above, except as covered separately in subsequent tasks. The effort will also include participation in program change control, PERT technical support, preacquisition evaluation and installation of special test equipment, and government furnished equipment.

Activation of Test and Checkout Facility

This task will utilize data on the operational needs and specifications of the selected checkout system to develop design criteria for the installation and operation of the system in NR Space Division Building 290. The Facilities Design group will convert the criteria into construction drawings and specifications for the required modifications and utilities.

Material Handling/Parts Protection Equipment

Since it is desired to use the same material handling equipment for test articles and flight articles, it will be necessary to establish an interface with engineering early in the program to obtain needed design criteria. Detailed drawings and specifications for the fabrication or purchase of equipment will be accomplsihed in the Facilities Design group. Production of hardware items is planned for the Tooling department in Building 1.

Minimum requirements for material handling equipment and parts protection devices are:

Item No.	Item Description
1	LFV dolly
1A	LFV sling
1B	LFV protective cover
2	Leg dolly
2A	Protective cover
3	Console dolly
3A	Protective cover
4	Tank dolly - (1) oxidizer, (1) fuel, (2) helium
4A	Tank covers
5	Truss structure dolly
6	Engine dolly

Facilities Support for Propulsion Tests

Initial activity of this task will involve evaluation of the existing Santa Susana Field Laboratory capabilities, especially those at Components Test Laboratory 4. At the same time, close coordination will be maintained with program engineering to ascertain test requirements. When the requirements have been sufficiently defined, final site selection will be made and the necessary detailed drawings and specifications will be made for the modification of and additions to the selected site.

Liaison with Rocketdyne F&IE will be established and procedures for the operation and surveillance of CTL 4 activity established.

Schedule and Major Milestones

The one-man lunar flying vehicle facilities schedule (Figure 11) provides the time lapse phasing and major milestones of the five principle task areas of F&IE participation covered generally in the task description.

The final facilities plan will be completed by the end of the second quarter under contract and will provide direction and guidelines for all F&IE work including burden activity, such as minor rearrangements necessitated by the engineering, test, or manufacturing requirements of the program.

Facilities technical support will be active for the total contract period. The task will provide an interface with all program areas and include participation in program change control, special test equipment evaluation and procurement support. Liaison with program activities and anticipated support functions, not specifically covered in subsequent tasks, are summarized in the following listing:

Date	Location	Activity
10-69	B/2	Establish initial office area
3-70	B/2	Provide administration and engineer area
	B/1, B/4, B/299, B/288	Support engineer design criteria laboratory programs
1-70	B/18	Support mockup fabrication
6-70	B/1	Support test article production
9-70	B/288	Support structural test
10-70	Site 635	Support landing test
	LAD B/260	Support dynamic test
3-71	B/1 & B/287	Support flight article fabrication
6-71	B/290	Support assembly and test
12-70	B/1, B/4, B/287, B/299	Support quality, test, and failure analysis programs

Preacquisition evaluation and identification of long procurement lead-time items associated with final test and checkout equipment will be conducted to permit the accomplishment of the activation of test and checkout facilities within the limited schedule period.

The activation of test and checkout facilities task will provide the design, construction, and surveillance of services and utilities required to support the final acceptance test systems. Criteria development and interfaces with involved organizations will be provided by the facilities technical support

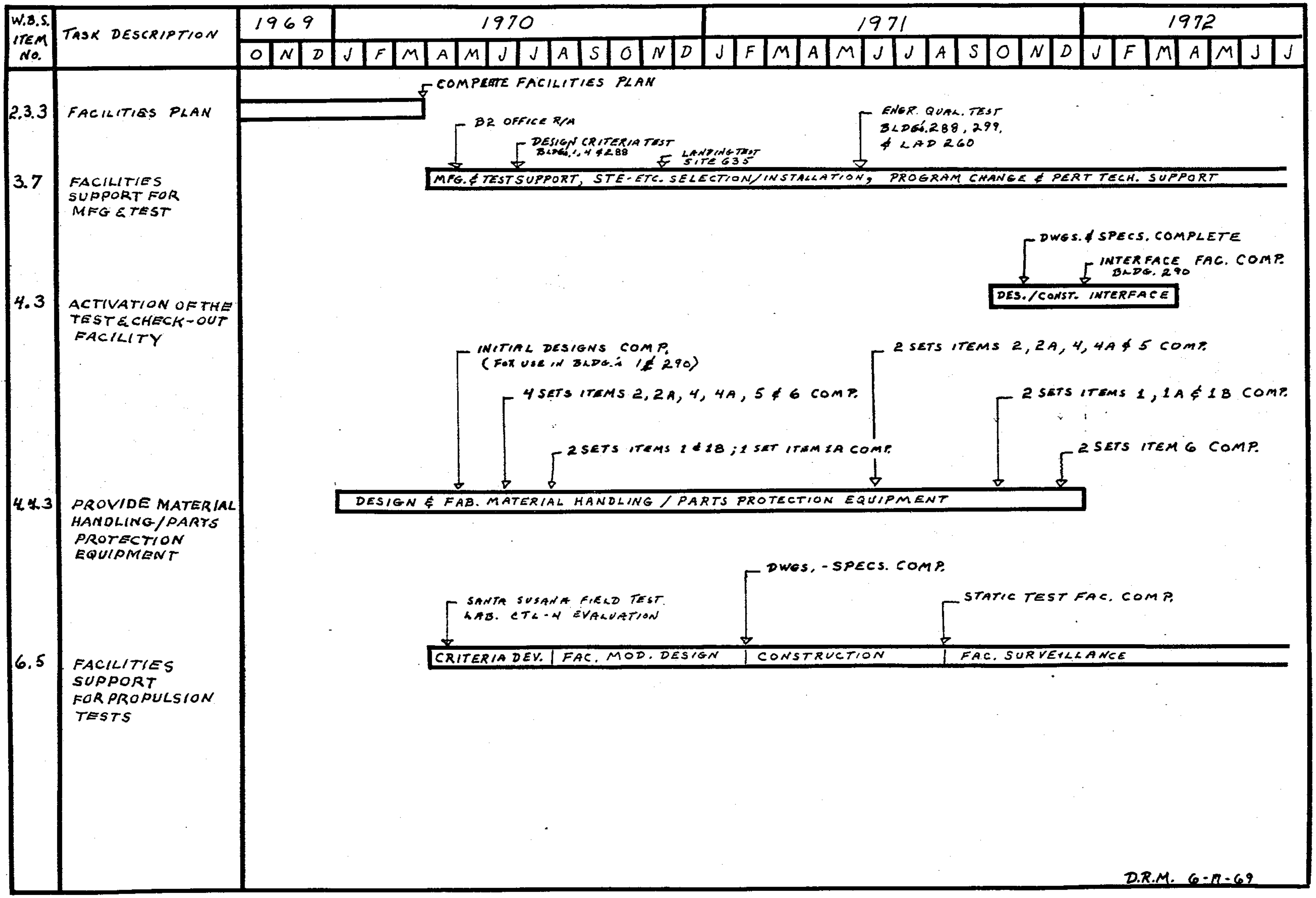


Figure 11. LFV Phases C and D Facility Schedule

task. This function will provide the utilities, such as electrical power and high-pressure gas, and facility modifications required in Building 290 to interface with the LFV checkout system.

Material handling parts protection activity begins early in the program in order that equipment will be available for the fabrication and assembly of all test articles made with "hard" tooling. Milestones on the schedule identify the phasing of equipment necessary for program support and optimization of fabrication and storage. All jigs, dollies, fixtures, and protective devices required for the fabrication and subassembly of parts in Buildings 1 and 287 and final assembly and checkout in Building 290 will be provided by this effort.

The propulsion system test task is scheduled to evaluate existing capability at the Santa Susana Field Laboratory early in the program, and interface with engineering to obtain the specific requirements of the test program. After design and construction, the schedule shows continuing effort to cover liaison with the Rocketdyne Division and provide for surveillance requirements that the interdivision activity may incur. Major milestones are the completion of a design package for modification of existing facilities to meet test requirements and the operational readiness of the facility in time to support the test program.

Anticipated activity will be:

1. Liaison with program engineering and facilities personnel at the Rocketdyne Field Laboratories to determine test parameters and the optimum test site at CTL-4 complex at Santa Susana.

2. Reduce data from item 1 to facility design criteria.

3. Design CTL-4 modification.

4. Implement modification.

5. Surveillance of test activity.

Available Facilities

The facilities are grouped in three basic activity areas:

1. Administration and engineering offices
2. Production facilities
3. Laboratories and test facilities

Figures 12, 13, and 14 show the location of NR facilities.

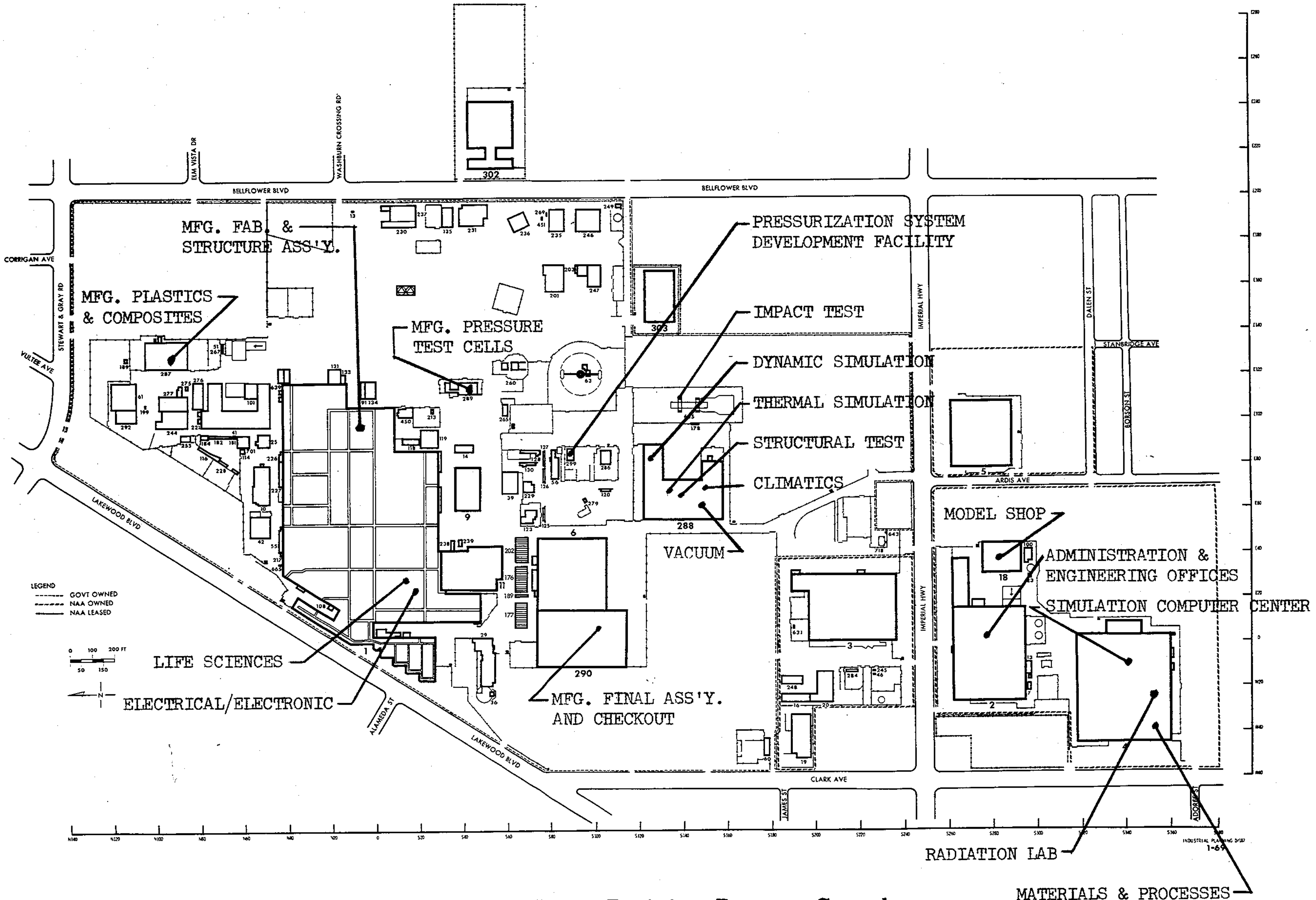


Figure 12. Space Division Downey Complex

Space Division
North American Rockwell

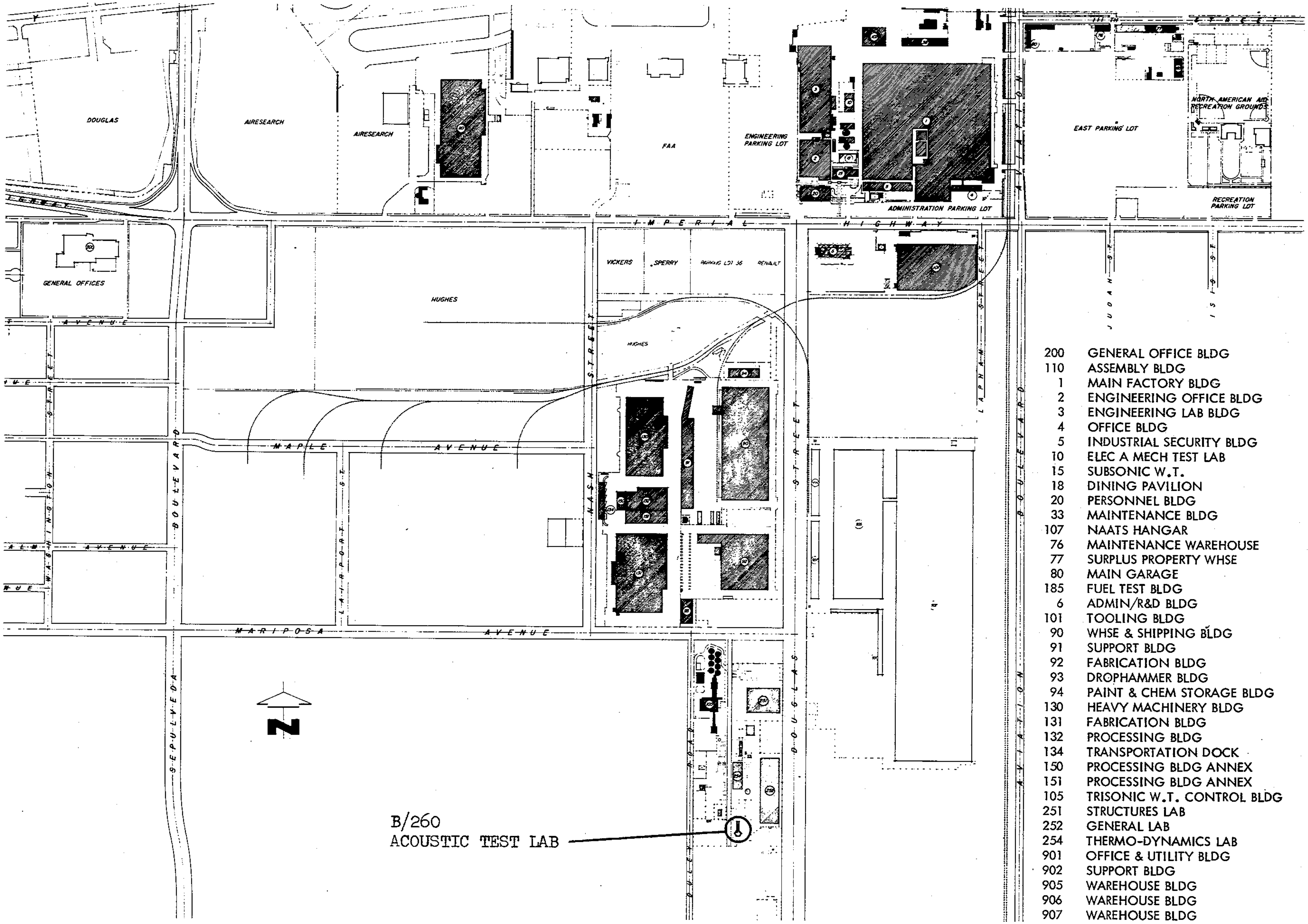


Figure 13. Los Angeles Division Site Plan, International Airport

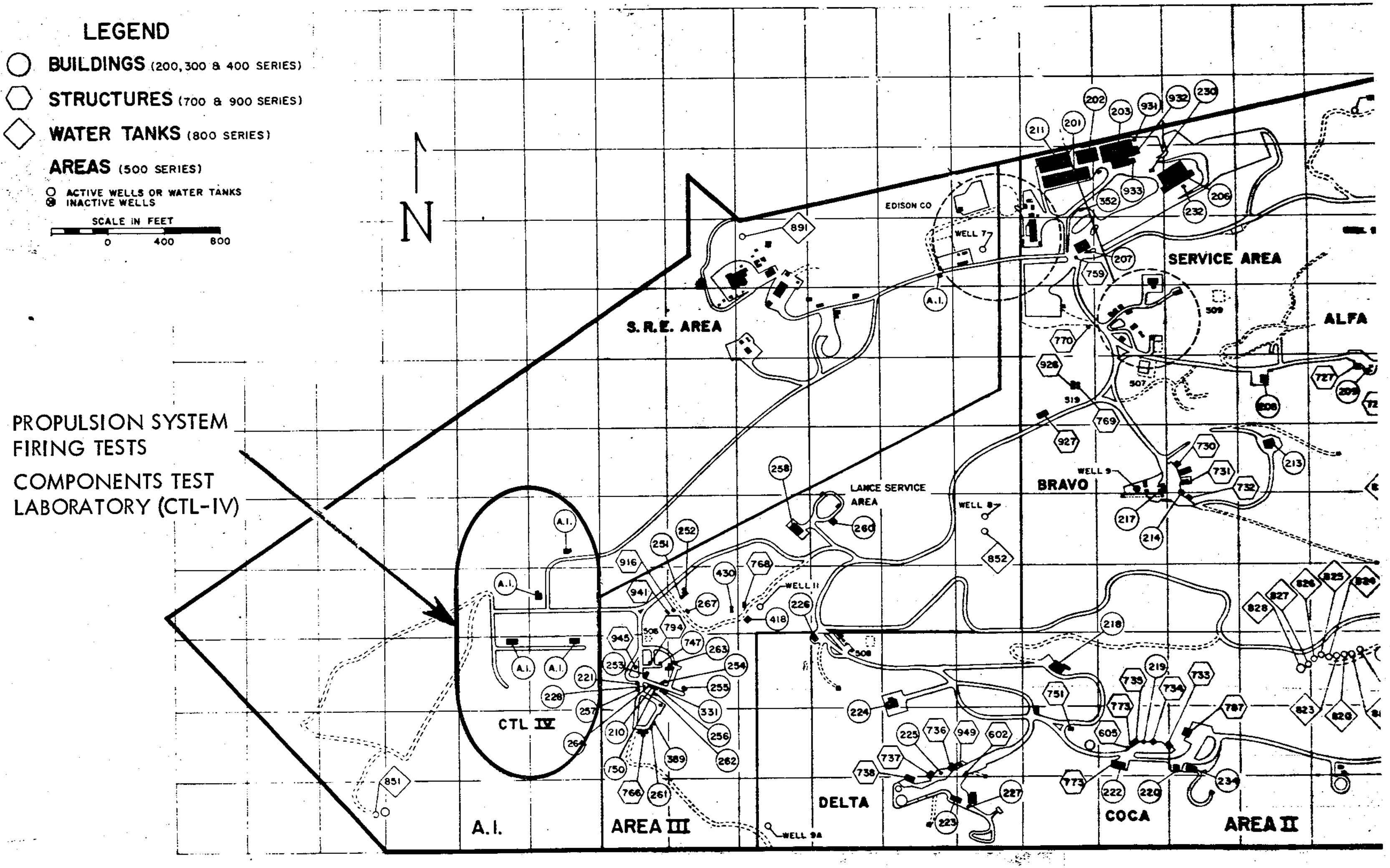


Figure 14. Rocketdyne Division Santa Susana Field Laboratory

Administration and Engineering Offices

Project management and engineering personnel will be located in company-owned Building No. 2, which is also the headquarters for the management and technical staff of the Research, Engineering, and Test and the Advanced Programs Divisions. Its proximity to the Computer Center and other support areas facilitates communications and allows full concentration and control of effort on the project. One IBM 360 Model 20 satellite computer is available in Building No. 2 for remote entry into the IBM 360-50/65 ASP (attached support processor) system.

Production Facilities

Detail parts, components, and structural members for the basic structures of test vehicles and flight articles will be fabricated and assembled in Building 1, Downey. Components for the systems, not obtained from subcontract sources, also will be fabricated in this facility. Plastic and composite material components will be produced in Building 287. Final installation of systems and components onto the basic structure and subsequent checkout will be accomplished in environmentally controlled areas of Building 290. For safety purposes, proof pressure and leakage tests of pneumatic systems will be conducted in environmentally controlled test cells of Building 289.

The fabrication and assembly of the software mockups will be accomplished in company-owned Building 18, Downey. The engineering support shop provides Space Division engineering groups with the fabrication of mockups, test articles, first articles, models, and prototypes, and assists in the development of new designs and fabrication techniques. This shop, part of Manufacturing, is operated primarily to support engineering projects that require highly specialized equipment and skills. The department has three major sections: the machine shop, sheet metal shop, and wood shop. The department also has plastics, welding, and electronics fabrication capability. The shop has more than 50 items of modern equipment and has highly trained workers capable of conducting an integrated engineering/manufacturing program in conformance with specific quality assurance and program control procedures.

Laboratories and Test Facilities

In the Laboratories and Test Facilities, special equipment and experienced personnel with extensive laboratory testing backgrounds make possible all types of developmental testing. This capability covers materials, processes, structural, and dynamic testing. Instrumentation and computation groups are used to provide rapid recording and interpretation of data. Affiliated design and fabrication groups expedite the production and deployment of test apparatus.

Activities utilizing these facilities can be divided into two groups: (1) design criteria development and (2) design verification and engineering qualification. Laboratories such as the Life Sciences complex of Building 1, the materials and processes facilities, and the radiation laboratory of Building 4 will provide data required by engineering to establish design parameters. Design verification and engineering qualification include tests conducted in the dynamic simulation, climatics, thermal simulation, vacuum and structural test areas of Building 288, the Building 299 pressurization system development facility, the Building 260 acoustic facility of the Los Angeles Division, and the field test laboratory of the Rocketdyne facility.

<u>Computing and Data Systems Services, Building 4.</u> Space Division's digital computing and data processing center is located in the company-owned Building No. 4. This facility also houses the Simulation Center with its analog computers, and a portion of the Division's research laboratories. Digital computers available to this project include four IBM 360 Model 20's, two IBM 360 Model 30's, two IBM 360 Model 50's, and three IBM 360 Model 65's. There is also a Stromberg-Carlson 4020 CRT optical or graphical plotter and an IBM Model 2250 graphic display station.

<u>Radiation Laboratory, Building 4.</u> Environmental control/space radiation laboratory provides a means of measuring sample changes when subjected to various types of particle bombardment while in a 10^{-6} torr environment. Radiation sources include ion, proton, OV, and a 4-inch beam solar simulator.

<u>Electrical-Electronics, Building 1.</u> This laboratory has the capability for research and development work, for performing certification tests, as well as the ability to service and condition electrical and electronic devices including those of electromagnetic, electrochemical, and electromechanical origin. The electrical insulating capabilities extend from wiring to complex molding and encapsulation of assemblies. Certification tests can be run on components or complete systems whether generating or storing energy, or converting, distributing, sensing, sequencing, or controlling electrical energy. Malfunction analysis, verification tests, and functional studies can be performed in these laboratories on pneumatic and hydraulic components and systems. These laboratories also have the capability of testing under simulated space conditions. The laboratories are equipped for conducting extensive hydrodynamic tests.

Dynamic Simulation, Building 288.

Force	Frequency Range
(Hydraulic), 100,000 pounds	0 to 500 cps
(Electrodynamic), 30,000 pounds	5 to 2,000 cps
(Combined) (2), 60,000 pounds	
(Lone-MB) (2), 3,500 pounds	
(Random and sine wave), 7,000 pounds	5 to 3,000 cps
(Random and sine wave), 8,000 pounds	5 to 3,000 cps (HF)
(Random and sine wave), 10,000 pounds	5 to 2,500 cps
(Random and sine wave), 10,000 pounds	5 to 3,000 cps
(Line-MBO), 1,200 cps	5 to 3,000 cps
(High-force thruster), 60,000 pounds	5 to 2,000 cps

Multishaker array - capability in excess of 60,000 pounds force.

Thermal Simulation, Building 288. This facility contains 36 channels of radiant heating control computers and ignitron power controllers; a transformer vault rated at 6,000 kva continuous and approximately 7,250 kva for five minutes; one 36-channel remote control console; an 8-channel parallel-entry digital temperature recording system; and miscellaneous multiple-channel recycling temperature and output voltage recorders. This facility can simulate boost as well as earth and planetary entry conditions of aerodynamic heating and/or shear. Also, effects of rocket exhaust and flame plume can be tested. Heat transfer and material studies for very high temperature testing in vacuum or inert atmosphere can also be accomplished. Research and development testing on thermal testing devices can also be performed.

Vacuum, Building 288. The vacuum facility contains specialized test equipment for subjecting spacecraft hardware and materials to combined space environment including high vacuum (10^{-4} to 10^{-11} torr), solar radiation, and temperature extremes. Man-rated altitude chamber (18 by 17 feet) can be evacuated to approximately 240,000 feet maximum altitude.

Structural Test, Building 288. The Structural Test Facility in the Space Systems Development Facility, Building 288, covers approximately 14,400 square feet. Imbedded in the floor of this area on 4-foot spacings are 39 floor beams that are 60-feet long and have a capability of reacting 75,000 pounds for each 10 feet of length. Two 5-ton capacity overhead cranes with hook heights of 35 feet can cover the entire floor area. Four test columns 24 feet high are located near the north wall of the facility. Each column has a capability of reacting 10,000 inch-pounds of moment.

Pressurization System Development Facility, Building 299. The proof pressure, leak test, and developmental test of the propulsion system is planned to be performed in the pressurization system development facility, Building 299. The specified tests will be performed in one of the three test cells. The test cells are utilized for proof-pressure, leakage, and performance evaluation of components, subsystems, and GSE end items at operational temperatures. The facility has pressure systems up to 20 lb/sec at 20,000 psi. Safety is emphasized throughout the facility. The building is separated from other facilities and is designed for hazardous operations. Test cell walls are 12-inch-thick concrete capable of withstanding an energy release equivalent to 10 pounds of TNT. Observation windows between the instrument room and test cells are made of bullet-resistant glass and have steel cross bars for additional protection. Comprehensive procedures and warning systems ensure safe and proper handling, transfer, and utilization of pressurized gases and liquid nitrogen.

Life Sciences, Building 1. This laboratory provides the means for measurement and experimental evaluation of human response to various stimuli. This is done to establish crew performance parameters and to evaluate their effect upon subsystem design and reliability. Crew capabilities and limitations, as the result of total subsystems integration, are evaluated in respect to controls, data displays, and lighting—both interior and exterior.

Impact Test Facility, Site 635. The impact test facility provides capability for testing vehicles for landings on water, earth, or lunar surface. The facility is capable of testing vehicles up to 10,000 pounds gross weight. Horizontal velocities are imparted from a long pendulum, which may be moved into position over either water or land impact test areas.

Tower structure statistics:

Maximum tower height = 143 feet
Height of catwalk and pendulum pivot = 125 feet
Length of pendulum arms = 91 feet

Power hoist capacities:

15-ton fixed hoists at each end of track
7-1/2 ton hoist in pendulum support trolley

Impact velocities (max)

38 fps (vertical)
52 ft/sec (horizontal)

The facility provides for controlled vehicle impact attitudes of pitch, roll, and yaw. Impact surfaces: water or land (with variable grades).

Los Angeles Division Acoustic Test Laboratory, Building 260. The sonic test laboratory is capable of generating narrow band, discrete frequencies from 25 to 10,000 cps at sound intensities up to 170 db over a 3-foot area, and intensities of 160 db in a reverberant room 10 feet x 14 feet x 25 feet. Random noise can be generated at frequency spectrum from 15 to 12,800 cps with an overall sound pressure level of 176 db at a 3-foot area and 161 db in the reverberant room. Measurement, recording, and analysis systems necessary for acoustic test programs are available in the laboratory.

Rocketdyne Division, Field Test Laboratory, Santa Susana. Propulsion testing for a large range of rocket systems is available at this site. Components Test Laboratory (CTL) 4 has been tentatively selected as the site of lunar flying vehicle engine firing tests. Firing stands, instrumentation and control capability, and support systems are existing and only minor modifications are anticipated to accommodate the lunar flying vehicle. Provisions for a limited flight test by suspending the vehicle from a crane by elastic cables have been included in the preliminary F&IE plan cost estimates.

PROGRAM COST SUMMARY

Cost data obtained from subcontract sources and manpower estimates and other cost estimates obtained from Space Division functional management were analyzed in arriving at the costs and manpower data presented in this section. The major assumptions employed in deriving these data include:

- GFY 1970 dollar values
- 10 percent fee
- The design defined in the Preliminary Design and Specification Volume of this report
- Costs do not include spares, new facilities, and LM integration (changes to LM relative to mounting, stowing, lunar unloading, and lunar refueling of LFV).
- Spacesuits and PLSS units assumed GFP if required for development tests.
- Support from LM contractor (Grumman), MSC flight crews, and MSC in-house test costs are excluded.
- Excludes costs for flight crew training (this is contained in a separate volume of this report).

A summary of the program costs is presented in Figure 15 as a function of Government fiscal year. The maximum expenditure of 22.5 million dollars occurs in 1971. The total program cost is 37.5 million dollars, with 28.15 million of these being non recurring costs and 9.35 million being recurring costs.

Figure 16 presents Space Division's average direct headcount as a function of Government fiscal year. A maximum direct headcount of 160 occurs during 1971.

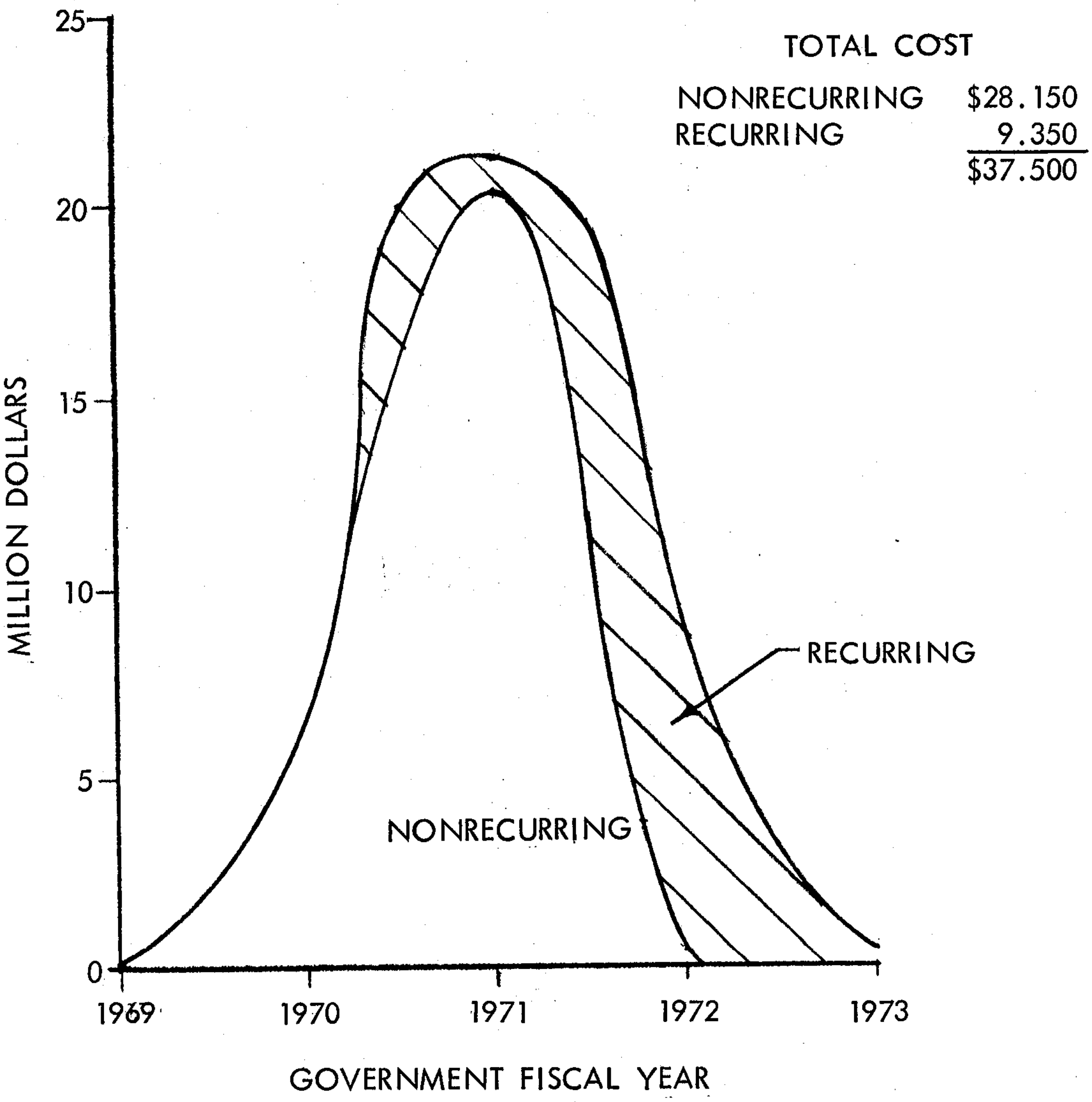


Figure 15. LFV Program Cost

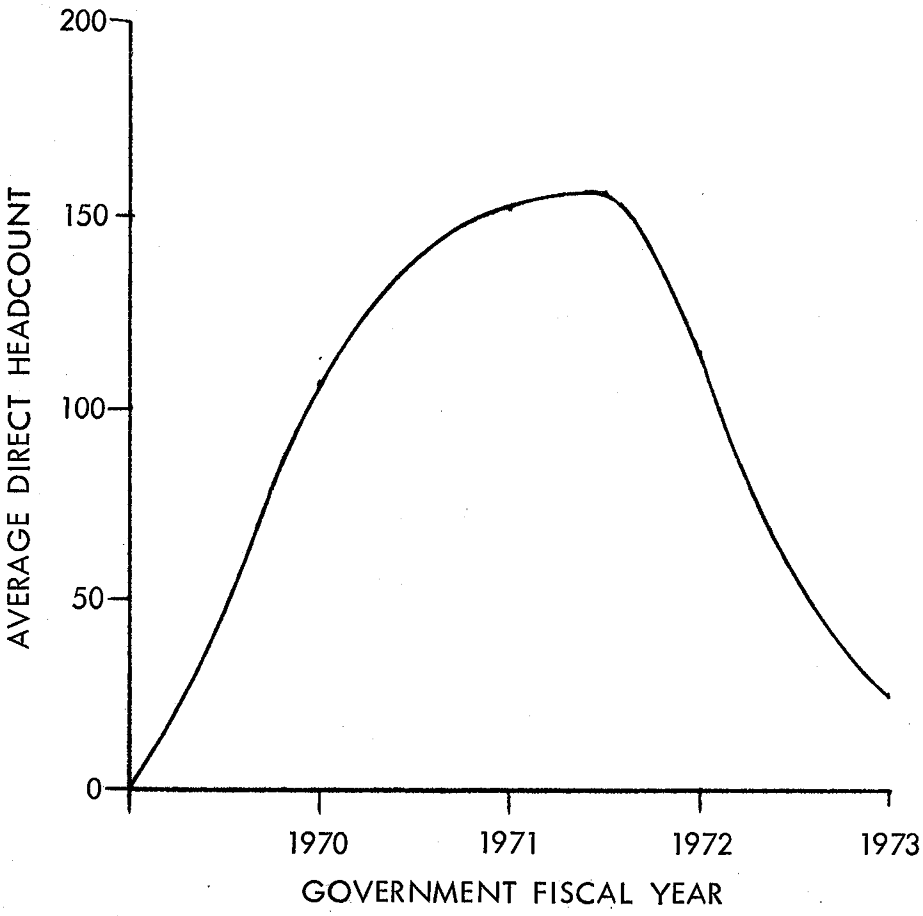


Figure 16. Space Division Manpower Requirements for LFV

PART II

TRAINING PLAN

II. TRAINING PLAN

SCOPE

All instruction will be limited to LFV crewman training objectives and specifically those astronaut activities related to the LFV mission.

The LFV crew training approach will be similar to the Apollo flight crew training philosophy. Prior to detailed academic and flight training, briefings will be provided for orientation, mission, and LFV systems familiarization.

Periodic updates will be provided as necessary to impart LFV hardware and software configuration changes that occur during the design phase.

Student evaluation and qualification will be the responsibility of the NASA/MSC.

CURRICULUM OVERVIEW

The training curriculum will be divided into three phases and will include both academic and practical flight training sessions.

The first phase will consist of general LFV systems and mission familiarization briefings.

The second phase will consist of academic sessions for the presentation of LFV systems functional and operational material and will be interleaved with practical sessions using an LFV full-scale mockup and visual simulation trainer.

The third and final phase of training will consist of actual flight exercises using atethered flight vehicle and a free-flight training vehicle.

LFV TRAINING PHASE DESCRIPTION

Phase I (Familiarization Training)

This phase provides to the student the initial orientation of the complete training program, LFV mission familiarization, mission requirements, design philosophy, concepts, and LFV systems.

The training will be conducted at facilities as directed by NASA. Instructors will conduct the training on a trip basis at locations other than Downey, California.

Phase I courses will be prepared and implemented by customer training specialists of the Logistics Training Department (D/671), Space Division, North American Rockwell Corporation, Downey, California.

Phase II (LFV Systems and Flight Prep Training)

This phase will provide a series of alternate academic and practical sessions to satisfy the detailed LFV astronaut ground training objectives as related to the following tasks:

A. Subsystems operation

B. Vehicle assembly

C. Fueling operations

D. Vehicle loading

E. Vehicle trim

F. Flight control

G. Preflight and checkout

H. Navigation

I. Contingency modes

J. Procedures (Introduction)

This training will be provided at locations where practical training equipment (mockups and visual simulators) have been made available and designated by NASA as LFV training vehicles.

The academic portion of Phase II training will be prepared and presented by the Logistics Training Department (D/671), Space Division, North American Rockwell Corporation, Downey, California. This department may secure the assistance of the Space Division's CSM Test Operations Pilot Technology group for practical training conducted on visual simulation or other flight training equipment located at SD, Downey.

Phase IIIA (Flight Training - Primary)

Flight training will provide practical instruction and exercises using simulation and actual flight hardware.

This section includes recommendations for training vehicles, their configuration requirements, and practical training schedules based on the present LFV mission planning.

Training requirements and recommendations for implementation are as follows:

1. Visual Simulation Requirements - This training should include visual training on a rotating base, simulated vehicle to (1) familiarize the crew with the appearance and mode of operation of all indicating gauges and controls of the Lunar Flyer; (2) acquaint the crew with the dynamic response characteristics of the vehicle as projected by an external visual display system; (3) familiarize the crew with mission timelines for various missions; and (4) train the crew in lunar navigation.

2. Partial Gravity Trainer - This training should be conducted using a tethered flight vehicle designed to resemble the actual LFV control and instrument arrangements, and the crew restraint system employed on the LFV. Ideally, the trainer should be capable of simulating motions in six degrees of freedom.

   The purpose of this training is to familiarize astronauts with flight characteristics of the LFV during takeoff, landing, and limited cruise conditions; and acquaint the crew with control feel and motion characteristics of the LFV.

   Unless otherwise directed, the NASA will be responsible for all Phase III training activities.

Phase IIIB (Flight Training - Advanced)

Advanced Phase III flight training should provide free-flight training in an LFV training vehicle. The vehicle should be so designed that the pilot station and restraint system duplicates the LFV. The trainer should also be designed to provide a full six degrees of freedom free-flight control.

The purpose of this training is to train astronauts in the use of the LFV by intensive use of an accurately scaled dynamic six degree of freedom flying vehicle; and to simulate other LFV mission activities.

PHASE I AND II CURRICULUM

The following courses will constitute the basic curriculum for the Phase I and II training program:

1. Lunar Flying Vehicle Mission and Subsystems Familiarization Briefing

   Course length - 4 hours
   Course number - LFV-F1

2. Lunar Flying Vehicle Structural Subsystem

   Course length - 4 hours
   Course number - LFV-ST-1

3. Lunar Flying Vehicle Electrical Power Subsystem

   Course length - 4 hours
   Course number - LFV-EPS-1

4. Lunar Flying Vehicle Propulsion Subsystem

   Course length - 6 hours
   Course number - LFV-PR-1

5. Lunar Flying Vehicle Stabilization and Control Subsystem

   Course length - 8 hours
   Course number - LFV-SCS-1

6. Lunar Flying Vehicle Crew Subsystem

   Course length - 8 hours
   Course number - LFV-CR-1

All course hours above are estimates to reflect the maximum hours required for classroom instruction and practical exercises on mockup or visual simulation hardware. These course lengths are subject to change after LFV and trainer hardware definition.

PHASES I AND II COURSE OUTLINES

COURSE: LFV Mission and Subsystems Familiarization Briefing

COURSE NO.: LFV-F1 HOURS: 4

TOPIC

I. Introduction

   A. Orientation

   B. Distribution of Training Material

   C. LFV Objectives

      1. Typical Mission

II. LFV Concepts and Design Philosophy

   A. Considerations

      1. Structural

      2. Propulsion

      3. Control

      4. Instrumentation

   B. Surviving Concepts and Rationale

COURSE: LFV Structures

COURSE NO.: LFV-ST-1 HOURS: 4

TOPIC

I. Introduction

A. Objectives

B. Distribution of Material

II. Structural Component Description

A. Main Frame

B. Landing

C. Impact Attenuators

D. Couch and Restraints

E. Payload Carrier

III. Lunar Module LM Interface

A. Mounting (Transport)

B. Removal and Assembly

COURSE: LFV Electrical Power Subsystem

COURSE NO.: LFV-EPS-1 HOURS: 4

TOPIC

I. Introduction

A. Objectives

B. Distribution of Course Material

II. LFV Power Requirements

A. Direct Current

B. Alternating Current

III. Power Sources

A. AC

B. DC

C. Distribution

D. Protection Circuits

E. Display

IV. Flight Test and Contingency Modes

COURSE: LFV Propulsion System

COURSE.: LFV-PR-1 HOURS: 6

TOPIC

I. Introduction

A. Objectives

B. Distribution of Material

II. Propulsion

A. Control

1. Throttle

B. Propellants

1. Hypergolic

2. Fuel and Oxidizer Storage

a. Fuel tanks and flow system

b. Oxidizer tanks and flow system

3. Motive Force

a. Helium tanks and flow system

4. Propellant Flow Control

C. Engine Characteristics

III. Controls and Displays

A. Hand Controller and Stability System Interface

B. Propellant Gauging

C. Failure Analysis

IV. Fueling Operation and Equipment

COURSE: LFV Stabilization and Control Subsystem

COURSE NO.: LFV-SCS-1 HOURS: 8

TOPIC

I. Introduction

  A. Objectives

  B. Distribution of Material

II. Propulsion Requirements and Interface

  A. Thrust on/off Commands and Variable Control

  B. Gimbaling (thruster)

III. Stability Augmentation Equipment

  A. Rate Sensing and Integration Electronics

    1. Throttling Circuits

    2. Gimbal Circuits

IV. Controls and Displays

  A. Monitor Devices

  B. Control Devices

    1. Attitude Reference

    2. Attitude Control

    3. Thrust Vector Control

V. Pre-flight Trim

COURSE: LFV Crew Equipment

COURSE NO.: LFV-CR-1 HOURS: 8

TOPIC

I. Introduction

  A. Objectives

  B. Distribution of Material

II. LFV/Crewman Interface

  A. Couch

    1. Harness - Restraints

    2. Adjustments/Operational Positions

III. Life Support System Interface

  A. Suit and Environmental Control

  B. Communications

IV. Special Equipment/Storage

  A. Tools

  B. Experimental Equipment

V. LFV Procedures

  A. Pre-flight Checkout

  B. Flight

  C. Assembly

  D. Fueling

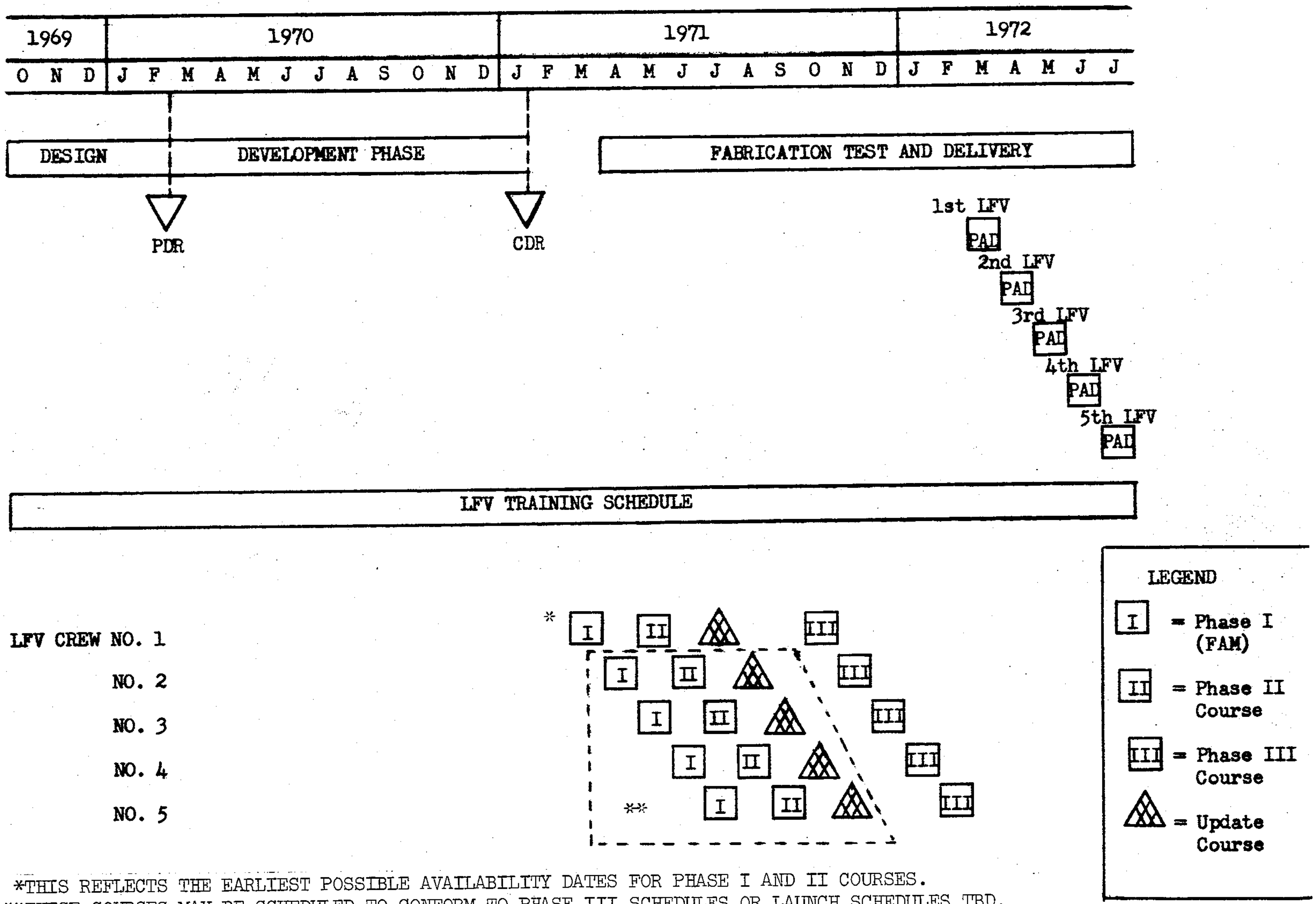
TRAINING SCHEDULES

The training schedules contained within this section are based on the LFV phases C&D program development schedule. Programmed development and fabrication milestones from this schedule, and training preparation requirements were reviewed to establish the initial training availability dates.

Generally, Phase I (familiarization courses) will be available any time after the CDR plus one month. Phase II training will be available two months following the CDR, assuming that LFV mockups and simulation and flight training hardware (1/6 g vehicle or equivalent) are available.

Free-flight training should begin no later than four months prior to the first scheduled use of the LFV.

All schedules reflect suggested months for implementation of training. Specific dates are not identified in order to provide the flexibility required for integrating LFV training into other astronaut training and activity schedules.



*THIS REFLECTS THE EARLIEST POSSIBLE AVAILABILITY DATES FOR PHASE I AND II COURSES.
**THESE COURSES MAY BE SCHEDULED TO CONFORM TO PHASE III SCHEDULES OR LAUNCH SCHEDULES TBD. COMBINED CLASSES ARE ALSO POSSIBLE WHEN MORE THAN ONE CREW HAS BEEN IDENTIFIED - AND AVAILABLE.

Figure 17. LFV Program Milestones (Major - as Related to Training Unit Requirements)

TRAINING MANUALS AND AIDS

A training handout package for each LFV subsystem course will be prepared. The packages will consist of the appropriate subsystem functional diagrams and illustrations. This material will be prepared from the latest engineering information available. Visual aids will be created as required to support special training needs.

Copies of procedures related to the LFV flight and mission operations will be obtained and utilized during academic training sessions for student orientation.

TRAINING COST AND PLANNING FACTORS

The following is an estimate of hours and other costs required to support Phases I and II training:

Training - Preparation and conduct	*8,960 hours
Production art - Preparation of handout material	2,000 hours
Publications - Publish 15 basic handouts	$150.00

Travel - 25 trips for off-site planning, coordination and presentation of courses.

Total cost - $250,000

In addition to the above manpower requirements, procurement of other training aids will be required. These include:

1. A mockup for LM removal, ingress/egress training, payload interface training, mock refueling practice, and general subsystem arrangements.
2. A visual simulation facility.
3. A 1/6 - g tethered training vehicle
4. A free-flight training vehicle

The requirements of items 2, 3, and 4 are described in the Appendix. Since these facilities have not yet been designed, a good estimate of cost is not possible. The following costs of these procurements are, therefore, preliminary estimates.

1. Mockup - Includes vehicle mockup, LM corner compartment mockup, and servicing equipment mockup. $ 20,000
2. 1/6-g Tethered Training Vehicle - Assumes availability of FLEEP vehicle and includes control system and crew station modifications. $ 250,000

*These hours indicate those required for Phases I and II training support through the LFV program period as reflected by the present LFV program development schedule - Phases C and D. (4 instructors for 14 months)

3. Free-Flight Training Vehicle - Assumes modification of the LM free flight trainer and includes control system and crew station modifications. $ 650,000

4. Visual Simulation Facility - Assumes design and procurement of a ± 60 degree vertical and ± 90 degree horizontal spherical screen, a TV camera pickup and motion equipment, a TV projector, a moving base, and a crew station mockup. $ 800,000

Manpower and additional facilities associated with NASA in conducting the training program has not been included in these estimates.

APPENDIX

REQUIREMENTS FOR VISUAL AND FLIGHT SIMULATORS

Prior to and during the conduct of the One-Man Lunar Flying Vehicle contract, NR Space Division conducted visual and flight simulation to obtain comparisons between the candidate control system techniques.

VISUAL SIMULATION

Visual simulation was conducted in two facilities, both of which provided six degree-of-freedom simulation. Both utilized analog computers to derive driving signals for the visual display, instrumentation, and, when appropriate, a motion base.

The Space Division simulator, which was utilized during the pre-contract period, had a spherical screen with a limited field of view (± 28 degrees horizontal, and ± 14 degrees vertical). A TV image was displayed on this screen by flying a TV camera over a large, three-dimensional lunar scene. The camera was pitched, rolled, yawed, and translated in three degrees of freedom utilizing input from the analog computers. This scene had the advantages of good contrast and yielded an apparent three-dimensional characteristic because of the ability to fly between mountains and craters. The major deficiency was the restricted field of view.

During the contract period, the NR Los Angeles Division HOTRAN facility was utilized for simulation. This facility allowed for cues from both a motion base (small-angle pitch and roll) and all six degrees of freedom on an 11-foot radius spherical scene. The screen gave excellent peripheral cues because of a ± 100 degree horizontal scene and a + 25 and - 65 degree vertical scene. The scene was obtained from a point light source projected through a photographic emulsion. Six degree-of-freedom visual motion was obtained by rotation and translation of the photographic emulsion. The advantages of this facility were the moving base (which provided pitch and roll motion onset cues) and the excellent peripheral vision. The main disadvantages were the poor contrast due to the low intensity of the light source and the lack of three-dimensional effects.

The current LFV design provides a very large field of available vision to the pilot when compared to the LM vehicle. Simulation has indicated that this large field of view is significant in flying the vehicle. Because of the large boost and deboost vehicle attitudes (± 45 degrees), the visual scene should provide about ± 60 degrees in the vertical plane. Horizontally, ± 90 degrees appears desirable. Because of the good quality of a TV picture, a mode of operation similar to the NR Space Division simulator is desirable. A base that rotates up to ± 10 degrees to provide motion onset cues is also desirable. Figure 18 schematically illustrates such a facility.

FLIGHT SIMULATION

Three types of flight simulation are required to provide astronaut training. (1) 1/6-g tethered basic trainer, (2) free-flight primary trainer, and (3) a helicopter. The 1/6-g vehicle will be utilized for initial landing practice under controlled conditions. The free-flight vehicle will be utilized for low-speed flight and landing practice following initial 1/6-g tethered training. The helicopter will be used for navigation training and for preparing the astronauts for flight over the lunar surface at velocities and altitudes associated with optimum flight (up to 375 feet per second at altitudes of 200 to 500 feet).

For a stability augmented control system, two possible routes could provide the 1/6-g trainer. The FLEEP vehicle, currently being procured, could be modified as illustrated in Figure 19 to provide the correct stability augmented system. Alternatively, the LM 1/6-g trainer could be modified to provide the LFV control system characteristics. Both vehicles should have the volumetric, display, and eye-ball altitude at landing characteristics similar to the LFV. Crew position and restraints should also be similar.

The free-flight trainer could be obtained by modifying the LM free-flight trainer to provide the correct control dynamic characteristics and the volumetric, display, and other essential characteristics similar to the LFV. This approach appears to be more economical than developing a new vehicle. When finally designed, it is likely that a new vehicle would approach the size of the LM trainer.

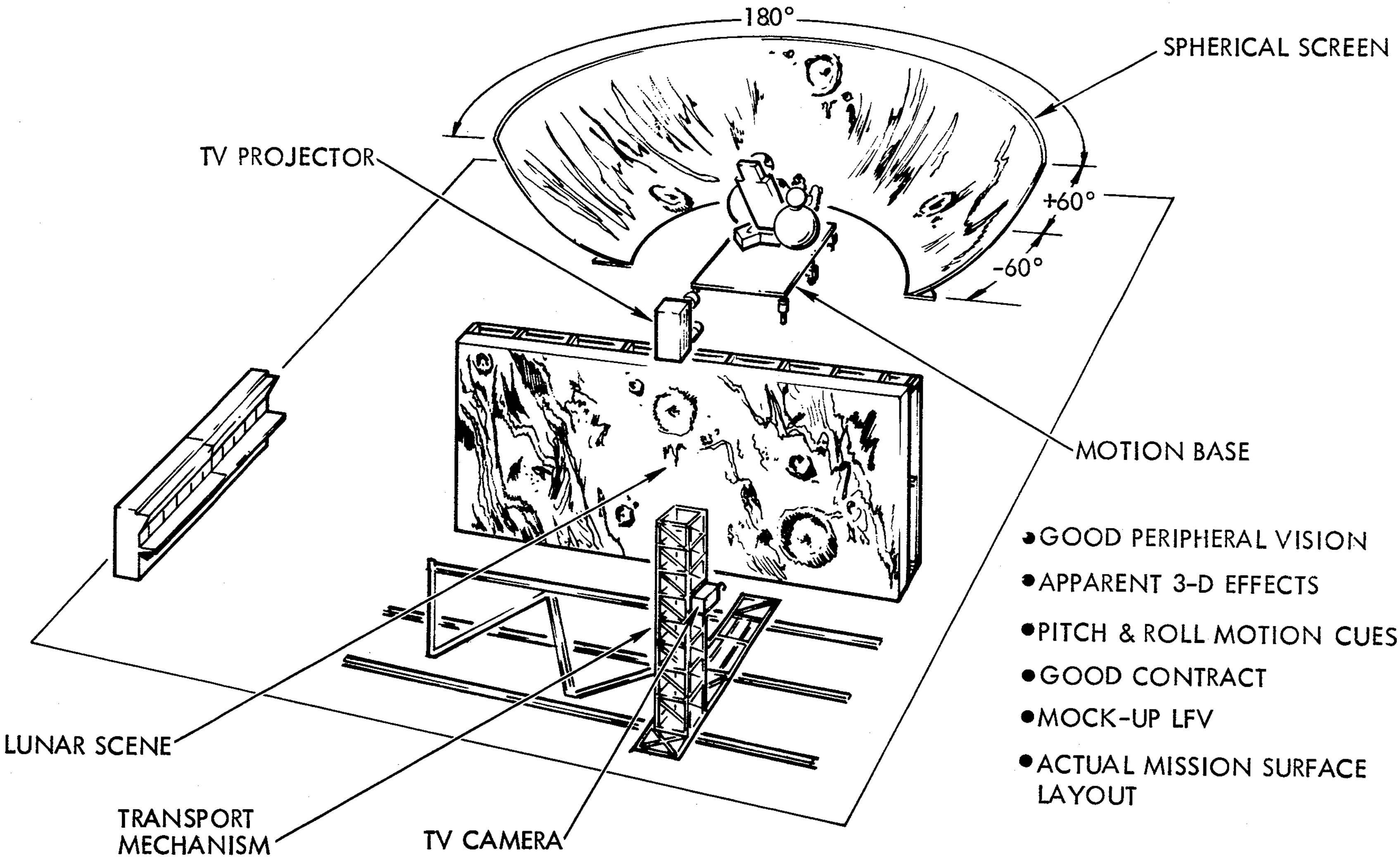
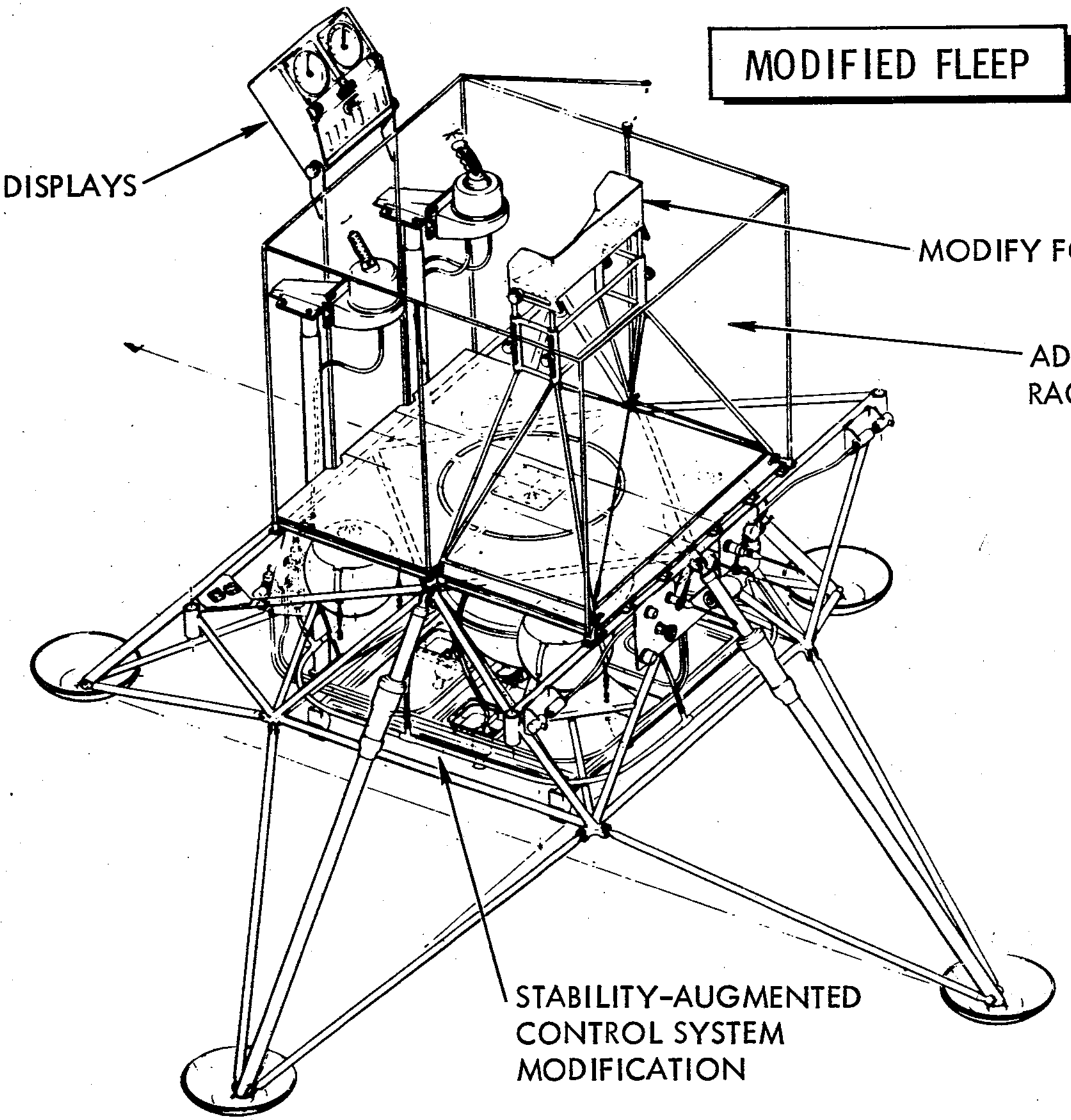


Figure 18. Visual Simulator Requirements



- FACILITY FOR 1/6-g FLT SUCH AS LLRF
- LFV DYNAMIC RESPONSE, CREW STATION (SEAT, RESTRAINTS, HAND CONTROLS, & DISPLAYS), LANDING EYEBALL ALTITUDE, & ESSENTIAL VEHICLE VOLUMES

Figure 19 . Tethered Flight System Requirements